Appendix A
Urban Tree Canopy Assessment Methodology

Davey Resource Group Classification Methodology for Urban Tree Canopy

Davey Resource Group utilized an object-based image analysis (OBIA) semi-automated feature extraction method to process and analyze current high-resolution color infrared (CIR) aerial imagery and remotely-sensed data to identify tree canopy cover and land cover classifications. The use of imagery analysis is cost-effective and provides a highly accurate approach to assessing your community's existing tree canopy coverage. This supports responsible tree management, facilitates community forestry goal-setting, and improves urban resource planning for healthier and more sustainable urban environments.

Advanced image analysis methods were used to classify, or separate, the land cover layers from the overall imagery. The semi-automated extraction process was completed using Feature Analyst, an extension of ArcGIS®. Feature Analyst uses an object-oriented approach to cluster together objects with similar spectral (i.e., color) and spatial/contextual (e.g., texture, size, shape, pattern, and spatial association) characteristics. The land cover results of the extraction process was post-processed and clipped to each project boundary prior to the manual editing process in order to create smaller, manageable, and more efficient file sizes. Secondary source data, high-resolution aerial imagery provided by each UTC city, and custom ArcGIS® tools were used to aid in the final manual editing, quality checking, and quality assurance processes (QA/QC). The manual QA/QC process was implemented to identify, define, and correct any misclassifications or omission errors in the final land cover layer.

Classification Workflow

1) Prepare imagery for feature extraction (resampling, rectification, etc.), if needed.
2) Gather training set data for all desired land cover classes (canopy, impervious, grass, bare soil, shadows). Water samples are not always needed since hydrologic data are available for most areas. Training data for impervious features were not collected because the City maintained a completed impervious layer.
3) Extract canopy layer only; this decreases the amount of shadow removal from large tree canopy shadows. Fill small holes and smooth to remove rigid edges.
4) Edit and finalize canopy layer at 1:2000 scale. A point file is created to digitize-in small individual trees that will be missed during the extraction. These points are buffered to represent the tree canopy. This process is done to speed up editing time and improve accuracy by including smaller individual trees.
5) Extract remaining land cover classes using the canopy layer as a mask; this keeps canopy shadows that occur within groups of canopy while decreasing the amount of shadow along edges.

6) Edit the impervious layer to reflect actual impervious features, such as roads, buildings, parking lots, etc. to update features.

7) Using canopy and actual impervious surfaces as a mask; input the bare soils training data and extract them from the imagery. Quickly edit the layer to remove or add any features. Davey Resource Group tries to delete dry vegetation areas that are associated with lawns, grass/meadows, and agricultural fields.

8) Assemble any hydrological datasets, if provided. Add or remove any water features to create the hydrology class. Perform a feature extraction if no water feature datasets exist.

9) Use geoprocessing tools to clean, repair, and clip all edited land cover layers to remove any self-intersections or topology errors that sometimes occur during editing.

10) Input canopy, impervious, bare soil, and hydrology layers into Davey Resource Group's Five-Class Land Cover Model to complete the classification. This model generates the pervious (grass/low-lying vegetation) class by taking all other areas not previously classified and combining them.

11) Thoroughly inspect final land cover dataset for any classification errors and correct as needed.

12) Perform accuracy assessment. Repeat Step 11, if needed.

Automated Feature Extraction Files

The automated feature extraction (AFE) files allow other users to run the extraction process by replicating the methodology. Since Feature Analyst does not contain all geoprocessing operations that Davey Resource Group utilizes, the AFE only accounts for part of the extraction process. Using Feature Analyst, Davey Resource Group created the training set data, ran the extraction, and then smoothed the features to alleviate the blocky appearance. To complete the actual extraction process, Davey Resource Group uses additional geoprocessing tools within ArcGIS®. From the AFE file results, the following steps are taken to prepare the extracted data for manual editing.

1) Davey Resource Group fills all holes in the canopy that are less than 30 square meters. This eliminates small gaps that were created during the extraction process while still allowing for natural canopy gaps.

2) Davey Resource Group deletes all features that are less than 9 square meters for canopy (50 square meters for impervious surfaces). This process reduces the amount of small features that could result in incorrect classifications and also helps computer performance.

3) The Repair Geometry, Dissolve, and Multipart to Singlepart (in that order) geoprocessing tools are run to complete the extraction process.

4) The Multipart to Singlepart shapefile is given to GIS personnel for manual editing to add, remove, or reshape features.

Urban Tree Canopy Accuracy Assessment Protocol

Determining the accuracy of spatial data is of high importance to Davey Resource Group and our clients. To achieve to best possible result, Davey Resource Group manually edits and conducts thorough QA/QC checks on all urban tree canopy and land cover layers. A QA/QC process will be completed using ArcGIS® to identify, clean, and correct any misclassification or topology errors in the final land cover dataset. The initial land cover layer extractions will be edited at a 1:2000 quality control scale in the urban areas and at a 1:2500 scale for rural areas utilizing the most current high-resolution aerial imagery to aid in the quality control process.

To test for accuracy, random plot locations are generated throughout the city area of interest and verified to ensure that the data meet the client standards. Each point will be compared with the most current NAIP high-resolution imagery (reference image) to determine the accuracy of the final land cover layer. Points will be classified as either correct or incorrect and recorded in a classification matrix. Accuracy will be assessed using four metrics: overall accuracy, kappa, quantity disagreement, and allocation disagreement. These metrics are calculated using a custom Excel® spreadsheet.

Table 1. Land Cover Classification Code Values

Land Cover Classification	Code Value
Tree Canopy	1
Impervious	2
Pervious (Grass/Vegetation)	3
Bare Soil	4
Open Water	5

Land Cover Accuracy

The following describes Davey Resource Group's accuracy assessment techniques and outlines procedural steps used to conduct the assessment.

1. *Random Point Generation*—Using ArcGIS, 1000 random assessment points are generated.

2. *Point Determination*—Each point is carefully assessed by the GIS analyst for likeness with the aerial photography. To record findings, two new fields, CODE and TRUTH, are added to the accuracy assessment point shapefile. CODE is a numeric value (1–5) assigned to each land cover class (Table 1) and TRUTH is the actual land cover class as identified according to the reference image. If CODE and TRUTH are the same, then the point is counted as a correct classification. Likewise, if the CODE and TRUTH are not the same, then the point is classified as incorrect. In most cases, distinguishing if a point is correct or incorrect is straightforward. Points will rarely be misclassified by an egregious classification or editing error. Often incorrect points occur where one feature stops and the other begins.

3. *Classification Matrix*—During the accuracy assessment, if a point is considered incorrect, it is given the correct classification in the TRUTH column. Points are first assessed on the NAIP imagery for their correctness using a "blind" assessment—meaning that the analyst does not know the actual classification (the GIS analyst is strictly going off the NAIP imagery to determine cover class). Any incorrect classifications found during the "blind" assessment are scrutinized further using sub-meter imagery provided by the client to determine if the point was incorrectly classified due to the fuzziness of the NAIP imagery or an actual misclassification. After all random points are assessed and recorded; a classification (or confusion) matrix is created. The classification matrix for this project is presented in Table 2. The table allows for assessment of user's/producer's accuracy, overall accuracy, omission/commission errors, kappa statistics, allocation/quantity disagreement, and confidence intervals (Figure 1 and Table 3).

Table 2. Classification Matrix

	Classes	Tree Canopy	Impervious Surfaces	Grass & Low-Lying Vegetation	Bare Soils	Open Water	Row Total	Producer's Accuracy	Errors of Omission
Reference Data	Tree Canopy	153	10	2	0	0	165	92.73%	7.27%
	Impervious	7	752	5	3	0	767	98.04%	1.96%
	Grass/Vegetation	0	8	37	0	0	45	82.22%	17.78%
	Bare Soils	0	0	0	6	0	6	100.00%	0.00%
	Water	0	0	0	0	17	17	100.00%	0.00%
	Column Total	160	770	44	9	17	1000		
	User's Accuracy	95.63%	97.66%	84.09%	66.67%	100.00%		Overall Accuracy	96.50%
	Errors of Commission	4.38%	2.34%	15.91%	33.33%	0.00%		Kappa Coefficent	0.9081

4. Following are descriptions of each statistic as well as the results from some of the accuracy assessment tests.

   Overall Accuracy – Percentage of correctly classified pixels; for example, the sum of the diagonals divided by the total points ((153+752+37+6+17)/1000 = 96.50%).

   User's Accuracy – Probability that a pixel classified on the map actually represents that category on the ground (correct land cover classifications divided by the column total [153/160 = 95.63%]).

   Producer's Accuracy – Probability of a reference pixel being correctly classified (correct land cover classifications divided

by the row total [153/165 = 92.73%]).

Kappa Coefficient – A statistical metric used to assess the accuracy of classification data. It has been generally accepted as a better determinant of accuracy partly because it accounts for random chance agreement. A value of 0.80 or greater is regarded as "very good" agreement between the land cover classification and reference image.

Errors of Commission – A pixel reports the presence of a feature (such as trees) that, in reality, is absent (no trees are actually present). This is termed as a false positive. In the matrix below, we can determine that 4.38% of the area classified as canopy is most likely not canopy.

Errors of Omission – A pixel reports the absence of a feature (such as trees) when, in reality, they are actually there. In the matrix below, we can conclude that 7.27% of all canopy classified is actually classified as another land cover class.

Allocation Disagreement – The amount of difference between the reference image and the classified land cover map that is due to less than optimal match in the spatial allocation (or position) of the classes.

Quantity Disagreement – The amount of difference between the reference image and the classified land cover map that is due to less than perfect match in the proportions (or area) of the classes.

Confidence Intervals – A confidence interval is a type of interval estimate of a population parameter and is used to indicate the reliability of an estimate. Confidence intervals consist of a range of values (interval) that act as good estimates of the unknown population parameter based on the observed probability of successes and failures. Since all assessments have innate error, defining a lower and upper bound estimate is essential.

Confidence Intervals

Class	Acreage	Percentage	Lower Bound	Upper Bound
Tree Canopy	394.6	14.6%	13.9%	15.3%
Impervious Surfaces	2,098.5	77.6%	76.8%	78.4%
Grass & Low-Lying Vegetation	139.9	5.2%	4.7%	5.6%
Bare Soils	12.2	0.5%	0.3%	0.6%
Open Water	58.0	2.1%	1.9%	2.4%
Total	2703.2	100.00%		

Statistical Metrics Summary	
Overall Accuracy =	96.5%
Kappa Coefficient =	0.9081
Allocation Disagreement =	5%
Quantity Disagreement =	1%

Accuracy Assessment

Class	User's Accuracy	Lower Bound	Upper Bound	Producer's Accuracy	Lower Bound	Upper Bound
Tree Canopy	95.6%	94.0%	97.2%	92.7%	90.7%	94.7%
Impervious Surfaces	97.7%	97.1%	98.2%	98.0%	97.5%	98.5%
Grass & Low-Lying Vegetation	84.1%	78.6%	89.6%	82.2%	76.5%	87.9%
Bare Soils	66.7%	51.0%	82.4%	100.0%	100.0%	100.0%
Open Water	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Urban Tree Canopy Ecosystem Benefits Calculations

Air Quality

The i-Tree Canopy v6.1 Model was used to quantify the value of ecosystem services for air quality. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports air pollutant removal rates and monetary values for carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM) (Hirabayashi 2014).

Within the i-Tree Canopy application, the U.S. EPA's BenMAP Model estimates the incidence of adverse health effects and monetary values resulting from changes in air pollutants (Hirabayashi 2014; US EPA 2012). Different pollutant removal values were used for urban and rural areas. In i-Tree Canopy, the air pollutant amount annually removed by trees and the associated monetary value can be calculated with tree cover in areas of interest using BenMAP multipliers for each county in the United States.
To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for each of the five listed air pollutants.

Carbon Storage and Sequestration

The i-Tree Canopy v6.1 Model was used to quantify the value of ecosystem services for carbon storage and sequestration. i-Tree Canopy was designed to give users the ability to estimate tree canopy and other land cover types within any selected geography. The model uses the estimated canopy percentage and reports carbon storage and sequestration rates and monetary values. Methods on deriving storage and sequestration can be found in Nowak et al. 2013.
To calculate ecosystem services for the study area, canopy percentage metrics from UTC land cover data performed during the assessment were transferred to i-Tree Canopy. Those canopy percentages were matched by placing random points within the i-Tree Canopy application. Benefit values were reported for carbon storage and sequestration.

Stormwater

The i-Tree Hydro v6.0 Model was used to quantify the value of ecosystem services for stormwater runoff. i-Tree Hydro was designed for users interested in analysis of vegetation and impervious cover effects on urban hydrology. This most recent version (v6.0) allows users to report hydrologic data on the city level rather than just a watershed scale giving users more flexibility. For more information about the model, please consult the i-Tree Hydro v6.0 manual (http://www.itreetools.org).
To calculate ecosystem services for the study area (City of Somerville), land cover percentages derived for the project area were used as inputs into the model. Precipitation data from 2005-2012 was modeled within the i-Tree Hydro to best represent the average conditions over an eight year time period. Model simulations were run under a Base Case as well as an Alternate Case. The Alterative Case set tree canopy equal to 0% and assumed that impervious and vegetation cover would increase based on the removal of tree canopy. Impervious surface was increased 0.7% based on a percentage of the amount of impervious surface under tree canopy and the rest was added to the vegetation cover class. This process was completed to assess the runoff reduction volume associated with tree canopy since i-Tree Hydro

does not directly report the volume of runoff reduced by tree canopy. The volume (in cubic meters) was converted to gallons to retrieve the overall volume of runoff avoided by having the current tree canopy.

Through model simulation, it was determined that tree canopy decreases the runoff volume in the project area by 4,361,443 gallons per year using precipitation data from 2005-2012. This equates to approximately 11,052 gallons per acre of tree canopy (4,361,443 gals/11,052 acres).

To place a monetary value on storm water reduction, the cost to treat a gallon of storm/waste water was taken from McPherson et al 1999. This value was $0.04 per gallon. Tree canopy was estimated to contribute roughly $174,458 to avoided runoff annually to the project area.

Zoning Classifications

To assess tree canopy coverage in different zoning types, the eighteen zoning types in the 2019 Somerville Zoning Ordinance (https://www.somervillezoning.com/) were condensed into six broader categories as follows:

Zoning Classification from Zoning Code	Zoning Classification for UFMP
Assembly Square	Other Special Districts
Civic	Civic Special Districts
Commercial Business	Commercial Districts
Commercial Core 3	Commercial Districts
Commercial Core 4	Commercial Districts
Commercial Core 5	Commercial Districts
Commercial Industry	Commercial Districts
Fabrication	Commercial Districts
High Rise	Mid & High-Rise Districts
Mid Rise 3	Mid & High-Rise Districts
Mid Rise 4	Mid & High-Rise Districts
Mid Rise 5	Mid & High-Rise Districts
Mid Rise 6	Mid & High-Rise Districts

Neighborhood Residential	Residential Districts
not applicable	Rights-Of-Way (ROW)
Powderhouse School	Other Special Districts
Tufts University	Other Special Districts
Urban Residential	Residential Districts

Prioritized Planting Locations based on Tree Canopy Data

The following methodology was used to identify and prioritize planting locations throughout the City as part of the Tree Planting Plan (***Section 3.1***).

Prioritized Planting – Planting Location

A geographic information system (GIS) based planting prioritization scheme was created as part of the urban tree canopy analysis. The planting location polygons (representations) were created by taking all grass/open space and bare ground areas and combining them into one dataset. Non-feasible planting areas such as agricultural fields, recreational fields, and major utility corridors were removed from consideration. The remaining planting space was then converted to multipart features creating separate, distinct polygons for each location. Using zonal statistics, the priority grid raster was used to calculate an average value for each planting location polygon. The averages were binned into five (5) classes (Very Low, Low, Moderate, High, and Very High) with the higher numbers indicating higher priority for planting.

How Sites Were Prioritized

To identify and prioritize planting potential, the analysis assessed a number of environmental and demographic data, including proximity to hardscape, canopy fragmentation, floodplain proximity, soil permeability, slope, soil erosion factor (K-factor), urban heat island index, and proximity to bus routes and bike lanes. In addition, planting potential was prioritized in Environmental Justice areas (which include parameters of income, minority populations and English language isolation) and where there are vulnerable populations (elderly housing, schools, child care and medical centers). Each factor was assessed using data from various sources and analyzed using separate grid maps. Values between zero and four (with zero having the lowest priority) were assigned to each grid assessed. The grids

were overlaid and the values were averaged to determine the priority levels at an area on the map. A priority level ranging from Very Low to Very High was assigned to each area on the map based on the calculated average of all grid maps. Once the process of identifying priority was completed, the development of planting strategies followed. All potential planting sites were not treated equally as some sites were considered to be more suitable than others. Through prioritization, sites were ranked based on a number of factors pertaining to storm water reduction and a relative urban heat island index. While available planting sites may ultimately be planted over the next several decades, the trees that are planted in the next several years should be planned for areas in most need, and where they will provide the most benefits and return on investment.

Priority Ranking Variables

Dataset	Source	Weight
Urban Heat Island Index	Urban Tree Canopy Assessment	0.20
Proximity to Hardscape	Urban Tree Canopy Assessment	0.15
Floodplain Proximity	National Hydrologic Dataset	0.10
Soil Permeability	Natural Resource Conservation Service	0.10
Slope	National Elevation Dataset	0.10
Soil Erosion (K-factor)	Natural Resource Conservation Service	0.05
Canopy Fragmentation	Urban Tree Canopy Assessment	0.15
Equity	Massachusetts GIS Dataset	0.05
Vulnerable Population	Somerville GIS Dataset	0.05
Bus Routes and Bike Lanes	Somerville GIS Dataset	0.05

References

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Appendix B
i-Tree Streets Inputs and Reports

i-Tree Streets Inputs

The i-Tree Streets model uses specific inputs to calculate the ecosystem service benefits of trees. If no community-specific information is available, then the model uses a set of standard values based on the region the city is located. The following default regional economic inputs were used to run Somerville's i-Tree Streets model:

Benefit Prices	
Electricity ($/Kwh)	0.1401
Natural Gas ($/Therm)	1.408
CO2 ($/lb)	0.0033
PM10 ($/lb)	8.31
NO2 ($/lb)	4.59
SO2 ($/lb)	3.48
VOC ($/lb)	2.31
Stormwater Interception ($/gallon)	0.008
Average Home Resales Value ($)	291,000.00

i-Tree Streets Reports

The following i-Tree Streets reports were generated as part of Somerville's inventory analysis.

Somerville

Annual Benefits of Public Trees by Species ($/tree)

7/29/2020

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error
maple, Norway	53.40	1.49	9.46	10.09	48.49	122.94	(N/A)
pear, callery	36.47	1.21	7.39	8.77	88.80	142.64	(N/A)
maple, red	31.41	0.61	5.09	7.23	46.37	90.70	(N/A)
honeylocust	72.06	1.42	12.49	14.25	65.78	166.01	(N/A)
linden, littleleaf	49.69	0.94	8.27	9.76	30.54	99.19	(N/A)
ash, green	62.87	1.21	11.01	12.58	48.10	135.77	(N/A)
zelkova, Japanese	56.03	1.10	9.01	9.92	77.02	153.08	(N/A)
planetree, London	53.25	1.05	8.48	10.48	44.35	117.62	(N/A)
plum	18.38	0.42	2.86	2.52	11.07	35.25	(N/A)
Japanese tree lilac	10.19	0.20	1.53	1.26	9.25	22.41	(N/A)
cherry, kwanzan	15.64	0.33	2.41	2.06	10.46	30.91	(N/A)
oak, northern red	66.14	1.65	11.66	16.29	46.90	142.64	(N/A)
elm, hybrid	14.96	0.35	2.34	3.20	57.90	78.74	(N/A)
sweetgum	27.27	0.49	3.22	4.81	34.80	70.58	(N/A)
ash, white	48.91	0.93	8.47	9.97	44.71	112.99	(N/A)
oak, pin	34.95	1.01	6.17	8.92	50.42	101.47	(N/A)
Vacant (Do Not Plant)	2.22	0.03	0.38	0.19	4.29	7.11	(N/A)
maple, hedge	19.94	0.46	3.24	3.18	19.81	46.63	(N/A)
elm, american	42.95	1.23	8.46	11.89	74.31	138.84	(N/A)
goldenrain tree	9.59	0.18	1.43	1.18	9.12	21.50	(N/A)
Japanese pagodatree	40.31	0.77	6.65	9.12	46.04	102.89	(N/A)
ginkgo	6.96	0.13	1.07	0.99	10.84	19.99	(N/A)
maple, silver	82.49	1.85	15.86	24.96	44.34	169.50	(N/A)
elm, Siberian	25.83	0.70	4.79	6.77	65.40	103.50	(N/A)
hornbeam, European	14.55	0.29	2.14	3.42	47.09	67.49	(N/A)
maple, freeman	45.69	0.95	7.75	10.36	41.60	106.34	(N/A)
maple, amur	28.22	0.62	4.56	4.30	25.22	62.91	(N/A)
apple	17.90	0.31	2.87	2.73	13.71	37.53	(N/A)
serviceberry	17.35	0.36	2.65	2.24	10.74	33.33	(N/A)
elm, Chinese	15.75	0.38	2.50	3.49	59.73	81.85	(N/A)
cherry, higan	4.13	0.07	0.58	0.48	8.02	13.28	(N/A)
basswood, American	48.92	1.12	8.53	12.32	59.50	130.38	(N/A)
linden, silver	4.93	0.13	0.80	1.18	28.73	35.78	(N/A)
oak, swamp white	14.87	0.34	2.17	2.98	39.43	59.78	(N/A)
sycamore, American	81.81	1.80	13.73	18.94	57.66	173.95	(N/A)
tree-of-heaven	81.75	1.62	15.64	21.87	85.88	206.76	(N/A)
maple, sugar	62.03	1.46	10.46	15.97	54.67	144.60	(N/A)
oak, scarlet	61.77	2.04	11.84	17.84	65.67	159.15	(N/A)
maackia, amur	1.34	0.04	0.18	0.23	47.34	49.12	(N/A)
hornbeam, American	27.03	0.51	4.11	6.09	46.80	84.53	(N/A)
chokecherry, common	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
cherry, yoshino flower	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
serviceberry, downy	12.57	0.25	1.90	1.57	9.74	26.03	(N/A)
serviceberry, Alleghen	2.42	0.04	0.34	0.29	7.50	10.59	(N/A)
oak, shingle	49.05	1.39	8.43	11.31	59.29	129.47	(N/A)
parrotia, persian	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
maple, sycamore	27.11	0.70	4.57	4.72	26.56	63.65	(N/A)
serviceberry, eastern	19.19	0.40	2.93	2.47	11.11	36.09	(N/A)
cedar, northern white	11.04	0.31	2.47	2.05	13.48	29.34	(N/A)
maple: Shangtung	2.22	0.03	0.38	0.19	4.29	7.11	(N/A)
maple, Japanese	16.03	0.34	2.54	2.41	16.53	37.86	(N/A)
katsura tree	21.93	0.41	3.79	5.15	46.35	77.64	(N/A)
hophornbeam, eastern	1.34	0.04	0.18	0.23	47.34	49.12	(N/A)

Annual Benefits of Public Trees by Species ($/tree)

7/29/2020

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error
tupelo, black	1.34	0.04	0.18	0.23	47.34	49.12	(N/A)
coffeetree, Kentucky	27.24	0.49	3.73	3.45	55.45	90.35	(N/A)
plum, cherry	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
catalpa, northern	64.00	1.18	11.44	16.55	43.04	136.20	(N/A)
unknown tree	13.12	0.25	2.25	4.93	36.11	56.65	(N/A)
pine, eastern white	54.93	0.97	10.69	16.02	18.49	101.10	(N/A)
mulberry, white	28.01	0.54	4.45	6.21	46.63	85.84	(N/A)
baldcypress	19.15	0.27	1.98	1.24	48.86	71.50	(N/A)
elm, slippery	61.31	1.79	12.40	17.26	85.35	178.09	(N/A)
maple, trident	1.22	0.03	0.18	0.26	6.20	7.88	(N/A)
beech, American	111.66	2.34	23.86	38.00	94.02	269.88	(N/A)
oak, English	44.02	0.83	6.55	8.05	39.02	98.47	(N/A)
boxelder	32.20	0.69	5.16	4.83	27.72	70.61	(N/A)
maple, miyabei	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
hardy rubber tree	12.31	0.16	1.09	0.47	44.18	58.22	(N/A)
tulip tree	32.83	0.50	3.77	2.76	58.22	98.07	(N/A)
spruce, Norway	59.35	1.04	11.61	17.12	16.78	105.90	(N/A)
cherry, black	34.39	0.98	5.52	5.31	15.21	61.41	(N/A)
birch, paper	58.24	1.19	9.48	10.04	79.51	158.47	(N/A)
cherry, sargent	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
spruce, Colorado	22.51	0.41	3.95	6.76	24.77	58.41	(N/A)
hawthorn	18.17	0.39	2.77	2.38	10.93	34.64	(N/A)
hackberry, northern	12.31	0.16	1.09	0.47	44.18	58.22	(N/A)
snowbell, Japanese	1.34	0.04	0.18	0.23	47.34	49.12	(N/A)
rose-of-sharon	6.59	0.12	0.96	0.79	8.51	16.97	(N/A)
yew	8.74	0.19	1.46	2.88	42.25	55.52	(N/A)
magnolia, Chinese ; m	8.16	0.15	1.21	0.98	8.82	19.31	(N/A)
juniper spp.	6.07	0.16	1.27	0.95	12.48	20.93	(N/A)
viburnum: spp.	4.15	0.09	0.83	0.57	8.39	14.02	(N/A)
birch, river	12.31	0.16	1.09	0.47	44.18	58.22	(N/A)
spruce, white	35.77	0.69	6.72	10.07	24.40	77.65	(N/A)
elm, rock	85.94	2.06	15.34	19.07	94.25	216.67	(N/A)
oak, white	43.35	1.21	7.33	9.96	56.56	118.40	(N/A)
hawthorn: cockspur	6.07	0.16	1.27	0.95	12.48	20.93	(N/A)
ash: European	38.43	1.17	9.05	7.61	27.78	84.06	(N/A)
spruce	7.13	0.13	0.98	2.60	23.75	34.60	(N/A)
hemlock, eastern	6.07	0.16	1.27	0.95	12.48	20.93	(N/A)
pear, common	19.06	0.62	3.51	4.17	64.49	91.86	(N/A)
maple	16.71	0.36	2.67	2.54	16.96	39.24	(N/A)
dogwood, flowering	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
beech, European	71.88	1.77	12.34	14.50	86.09	186.57	(N/A)
horsechestnut	72.69	2.83	12.60	19.90	82.71	190.73	(N/A)
pine: Japanese red	38.43	1.17	9.05	7.61	27.78	84.06	(N/A)
larch, European	97.63	2.06	18.95	25.98	108.40	253.01	(N/A)
cedar, atlantic white	6.07	0.16	1.27	0.95	12.48	20.93	(N/A)
sourwood	6.07	0.16	1.27	0.95	12.48	20.93	(N/A)
oak, sawtooth	6.70	0.10	0.89	0.96	31.51	40.16	(N/A)
unknown shrub	6.07	0.16	1.27	0.95	12.48	20.93	(N/A)
cherry, cornelian	12.85	0.24	1.94	1.56	9.76	26.36	(N/A)
ash	15.33	0.24	2.29	2.96	35.97	56.78	(N/A)
fringetree, White	27.00	0.45	4.29	3.99	17.97	53.70	(N/A)
hawthorn, Washington	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
Paradise apple	2.42	0.04	0.34	0.29	7.50	10.59	(N/A)
dogwood	12.85	0.24	1.94	1.56	9.76	26.36	(N/A)

Annual Benefits of Public Trees by Species ($/tree)

7/29/2020

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($)	Standard Error
oak	14.24	0.32	2.03	2.81	39.48	58.88	(N/A)
magnolia: cucumbertre	108.34	3.78	32.46	25.48	7.60	177.67	(N/A)
peach	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
mountainash: spp.	15.54	0.43	3.50	3.14	21.12	43.74	(N/A)
corktree, amur	63.59	1.25	10.80	14.07	45.17	134.88	(N/A)
magnolia, sweetbay	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
mulberry: spp.	60.11	1.62	14.83	13.26	27.75	117.57	(N/A)
birch, European white	63.59	1.25	10.80	14.07	45.17	134.88	(N/A)
magnolia, star	25.52	0.55	3.92	3.37	12.46	45.83	(N/A)
redbud, eastern	3.46	0.05	0.47	0.40	7.89	12.27	(N/A)
Citywide Total	43.43	1.00	7.54	8.91	50.40	111.29	(N/A)

Somerville

Replacement Value of Public Trees

7/29/2020

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	> 42	Total	Standard Error	% of Total
maple, Norway	538	7,780	562,687	1,580,961	969,318	628,216	181,925	52,425	20,675	4,004,524	(±0)	17.05
honeylocust	2,366	62,041	279,937	1,770,127	1,030,586	144,607	0	21,550	0	3,311,213	(±0)	14.10
linden, littleleaf	2,318	46,397	117,152	1,068,245	1,210,440	529,661	235,407	24,596	0	3,234,216	(±0)	13.77
maple, red	13,643	173,704	581,241	1,040,618	370,660	90,760	12,180	0	0	2,282,806	(±0)	9.72
ash, green	0	5,518	304,752	1,112,913	411,092	117,941	0	0	0	1,952,217	(±0)	8.31
pear, callery	5,394	110,823	498,887	762,933	158,060	6,493	0	0	0	1,542,589	(±0)	6.57
planetree, London	1,386	32,652	189,264	780,015	440,278	56,370	26,328	0	0	1,526,292	(±0)	6.50
zelkova, Japanese	6,595	67,539	152,865	570,242	574,089	14,330	0	0	0	1,385,661	(±0)	5.90
oak, northern red	1,804	15,549	27,749	117,796	344,999	348,431	168,021	30,690	34,310	1,089,348	(±0)	4.64
sweetgum	1,456	26,181	73,778	156,668	26,062	0	0	0	0	284,146	(±0)	1.21
maple, silver	328	908	11,116	13,148	11,954	43,826	86,984	56,877	27,715	252,856	(±0)	1.08
plum	15,428	36,997	77,460	67,142	24,240	3,787	0	0	0	225,055	(±0)	0.96
oak, pin	4,843	13,184	11,824	29,276	50,473	68,174	26,644	0	0	204,418	(±0)	0.87
ash, white	0	8,466	41,279	75,908	23,244	7,575	13,322	0	13,858	183,651	(±0)	0.78
elm, american	4,274	6,973	16,568	26,296	11,290	6,493	9,404	44,467	53,121	178,886	(±0)	0.76
cherry, kwanzan	7,816	34,335	51,180	50,991	0	0	0	0	0	144,321	(±0)	0.61
sycamore, American	0	370	3,296	30,696	67,456	9,628	13,994	18,503	0	143,942	(±0)	0.61
oak, scarlet	381	1,186	2,092	11,290	21,949	61,687	44,913	0	0	143,499	(±0)	0.61
Japanese pagodatree	897	1,625	22,052	82,789	26,062	0	0	0	0	133,424	(±0)	0.57
basswood, American	254	1,186	7,137	31,214	7,747	43,607	37,170	0	0	128,314	(±0)	0.55
maple, hedge	3,907	6,314	59,068	11,954	0	12,763	0	0	0	94,006	(±0)	0.40
Japanese tree lilac	17,783	33,837	34,605	0	0	0	0	0	0	86,225	(±0)	0.37
elm, hybrid	9,504	26,703	22,728	11,921	0	0	0	0	0	70,856	(±0)	0.30
maple, sugar	0	187	5,240	8,941	23,244	32,464	0	0	0	70,075	(±0)	0.30
maple, freeman	0	4,328	16,922	23,316	7,969	6,493	5,485	0	0	64,514	(±0)	0.27
beech, American	0	0	0	3,514	0	17,726	32,579	0	0	53,819	(±0)	0.23
tree-of-heaven	386	702	1,072	3,005	13,849	13,431	4,813	6,316	0	43,574	(±0)	0.19
maple, amur	298	2,163	30,026	7,969	0	0	0	0	0	40,456	(±0)	0.17
oak, shingle	0	0	5,661	34,534	0	0	0	0	0	40,195	(±0)	0.17
pine, eastern white	0	0	1,870	8,493	16,449	11,195	0	0	0	38,007	(±0)	0.16
spruce, Norway	0	0	0	11,290	7,747	18,081	0	0	0	37,118	(±0)	0.16
apple	1,697	2,365	18,589	10,543	0	0	0	0	0	33,194	(±0)	0.14
elm, Siberian	467	9,506	2,055	3,974	0	3,358	4,813	0	7,040	31,213	(±0)	0.13
ginkgo	3,427	7,792	11,162	6,311	0	0	0	0	0	28,692	(±0)	0.12
goldenrain tree	4,318	14,303	9,845	0	0	0	0	0	0	28,466	(±0)	0.12
serviceberry	745	3,837	21,289	0	0	0	0	0	0	25,871	(±0)	0.11
hornbeam, European	1,257	11,093	13,290	0	0	0	0	0	0	25,641	(±0)	0.11

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	> 42	Total	Standard Error	% of Total
elm, slippery	0	1,263	0	4,313	8,310	0	0	10,793	0	24,679	(±0)	0.11
catalpa, northern	0	0	2,549	0	7,969	0	9,404	0	0	19,922	(±0)	0.08
elm, Chinese	0	12,167	2,811	4,313	0	0	0	0	0	19,290	(±0)	0.08
hornbeam, American	149	488	13,660	0	0	0	0	0	0	14,297	(±0)	0.06
oak, swamp white	469	7,919	5,661	0	0	0	0	0	0	14,049	(±0)	0.06
linden, silver	3,083	1,430	0	0	7,747	0	0	0	0	12,260	(±0)	0.05
katsura tree	505	0	0	821	9,628	0	0	0	0	10,954	(±0)	0.05
maple, sycamore	0	2,218	1,163	3,044	3,422	0	0	0	0	9,847	(±0)	0.04
oak, English	0	0	9,845	0	0	0	0	0	0	9,845	(±0)	0.04
oak, white	0	0	2,536	6,977	0	0	0	0	0	9,514	(±0)	0.04
elm, rock	0	0	0	3,044	5,866	0	0	0	0	8,910	(±0)	0.04
cherry, black	0	0	991	2,104	5,645	0	0	0	0	8,740	(±0)	0.04
serviceberry, eastern	0	1,849	6,522	0	0	0	0	0	0	8,371	(±0)	0.04
cedar, northern white	359	1,012	2,953	3,985	0	0	0	0	0	8,309	(±0)	0.04
magnolia: cucumbertree	0	0	0	0	0	0	8,163	0	0	8,163	(±0)	0.03
coffeetree, Kentucky	512	628	0	6,311	0	0	0	0	0	7,451	(±0)	0.03
cherry, higan	5,967	641	0	0	0	0	0	0	0	6,608	(±0)	0.03
Vacant (Do Not Plant)	6,600	0	0	0	0	0	0	0	0	6,600	(±0)	0.03
horsechestnut	0	0	0	0	0	6,493	0	0	0	6,493	(±0)	0.03
corktree, amur	0	0	0	6,311	0	0	0	0	0	6,311	(±0)	0.03
beech, European	0	0	0	6,311	0	0	0	0	0	6,311	(±0)	0.03
ash: European	0	0	0	6,088	0	0	0	0	0	6,088	(±0)	0.03
larch, European	0	0	0	0	5,866	0	0	0	0	5,866	(±0)	0.02
maple, Japanese	359	419	5,045	0	0	0	0	0	0	5,823	(±0)	0.02
birch, paper	232	0	1,204	4,207	0	0	0	0	0	5,643	(±0)	0.02
spruce, white	0	0	1,477	3,985	0	0	0	0	0	5,461	(±0)	0.02
serviceberry, downy	447	1,221	3,569	0	0	0	0	0	0	5,236	(±0)	0.02
spruce, Colorado	0	0	5,060	0	0	0	0	0	0	5,060	(±0)	0.02
pine: Japanese red	0	0	0	4,313	0	0	0	0	0	4,313	(±0)	0.02
boxelder	0	0	4,248	0	0	0	0	0	0	4,248	(±0)	0.02
mulberry: spp.	0	0	0	0	3,422	0	0	0	0	3,422	(±0)	0.01
mulberry, white	467	0	1,832	678	0	0	0	0	0	2,977	(±0)	0.01
yew	0	1,186	1,477	0	0	0	0	0	0	2,663	(±0)	0.01
chokecherry, common	2,553	0	0	0	0	0	0	0	0	2,553	(±0)	0.01
cherry, yoshino flowering	2,253	0	0	0	0	0	0	0	0	2,253	(±0)	0.01
parrotia, persian	2,089	0	0	0	0	0	0	0	0	2,089	(±0)	0.01
maackia, amur	2,037	0	0	0	0	0	0	0	0	2,037	(±0)	0.01
hawthorn	134	0	1,842	0	0	0	0	0	0	1,976	(±0)	0.01
fringetree, White	0	0	1,870	0	0	0	0	0	0	1,870	(±0)	0.01
serviceberry, Allegheny	1,697	0	0	0	0	0	0	0	0	1,697	(±0)	0.01
plum, cherry	1,642	0	0	0	0	0	0	0	0	1,642	(±0)	0.01
baldcypress	381	1,186	0	0	0	0	0	0	0	1,567	(±0)	0.01

Species	DBH Class (in) 0-3	3-6	6-12	12-18	18-24	24-30	30-36	36-42	> 42	Total	Standard Error	% of Total
magnolia, star	0	0	1,477	0	0	0	0	0	0	1,477	(±0)	0.01
tulip tree	0	1,412	0	0	0	0	0	0	0	1,412	(±0)	0.01
maple: Shangtung	1,334	0	0	0	0	0	0	0	0	1,334	(±0)	0.01
pear, common	0	321	850	0	0	0	0	0	0	1,170	(±0)	0.00
maple, miyabei	1,161	0	0	0	0	0	0	0	0	1,161	(±0)	0.00
maple, trident	953	0	0	0	0	0	0	0	0	953	(±0)	0.00
hophornbeam, eastern	911	0	0	0	0	0	0	0	0	911	(±0)	0.00
juniper spp.	0	893	0	0	0	0	0	0	0	893	(±0)	0.00
tupelo, black	850	0	0	0	0	0	0	0	0	850	(±0)	0.00
spruce	0	837	0	0	0	0	0	0	0	837	(±0)	0.00
hardy rubber tree	783	0	0	0	0	0	0	0	0	783	(±0)	0.00
hemlock, eastern	0	739	0	0	0	0	0	0	0	739	(±0)	0.00
hawthorn: cockspur	0	739	0	0	0	0	0	0	0	739	(±0)	0.00
magnolia, Chinese ; magı	170	558	0	0	0	0	0	0	0	728	(±0)	0.00
unknown tree	0	198	179	0	351	0	0	0	0	727	(±0)	0.00
rose-of-sharon	396	321	0	0	0	0	0	0	0	717	(±0)	0.00
cherry, sargent	706	0	0	0	0	0	0	0	0	706	(±0)	0.00
mountainash: spp.	0	0	679	0	0	0	0	0	0	679	(±0)	0.00
birch, European white	0	0	0	678	0	0	0	0	0	678	(±0)	0.00
hackberry, northern	634	0	0	0	0	0	0	0	0	634	(±0)	0.00
cedar, atlantic white	0	593	0	0	0	0	0	0	0	593	(±0)	0.00
unknown shrub	0	524	0	0	0	0	0	0	0	524	(±0)	0.00
viburnum: spp.	134	370	0	0	0	0	0	0	0	504	(±0)	0.00
cherry, cornelian	0	443	0	0	0	0	0	0	0	443	(±0)	0.00
snowbell, Japanese	384	0	0	0	0	0	0	0	0	384	(±0)	0.00
birch, river	381	0	0	0	0	0	0	0	0	381	(±0)	0.00
sourwood	0	370	0	0	0	0	0	0	0	370	(±0)	0.00
maple	66	0	194	0	0	0	0	0	0	260	(±0)	0.00
dogwood, flowering	232	0	0	0	0	0	0	0	0	232	(±0)	0.00
magnolia, sweetbay	232	0	0	0	0	0	0	0	0	232	(±0)	0.00
peach	232	0	0	0	0	0	0	0	0	232	(±0)	0.00
hawthorn, Washington	191	0	0	0	0	0	0	0	0	191	(±0)	0.00
redbud, eastern	164	0	0	0	0	0	0	0	0	164	(±0)	0.00
Paradise apple	164	0	0	0	0	0	0	0	0	164	(±0)	0.00
oak, sawtooth	149	0	0	0	0	0	0	0	0	149	(±0)	0.00
dogwood	0	74	0	0	0	0	0	0	0	74	(±0)	0.00
oak	0	70	0	0	0	0	0	0	0	70	(±0)	0.00
ash	0	66	0	0	0	0	0	0	0	66	(±0)	0.00
Citywide Total	155,673	818,699	3,365,430	9,592,518	5,907,482	2,303,588	921,550	266,216	156,719	23,487,874	(±0)	100.00

APPENDIX C

Tree Inventory Data Collection and Site Location Methods

Data Collection Methods

DRG collected tree inventory data using Rover mobile mapping software. Rover is a GIS field data collection system built by DRG.

The software both collects data and processes data validations. Rover spatially joins features such as points, lines or polygons with GIS layers in order to derive data. The tool's GPS capabilities allow it to merge nearby camera hardware with the tablet computer to attach photos to features and render data on top of Google Terrain Maps, Google Hybrid Maps and Open Street Maps (when Internet connection is available.)

Rover's online and offline functionality gives field technicians the ability to directly distribute information to clients. Data uploads or electronic forms are transmitted to clients in real-time. The knowledge and professional judgment of DRG's arborists ensure the high quality of inventory data.

Data fields are defined in the glossary of the management plan. At each site, the following data fields were collected:

- address
- ash treatment candidate
- clearance requirements
- condition wood
- condition canopy
- gridling root
- grow space size – width
- grow space size – length
- grow space type
- further inspection
- hardscape damage
- location
- overhead utilities
- ownership
- park name
- primary maintenance needs
- mapping coordinates
- maintain ground
- new sidewalk
- notes
- risk assessment
- risk rating
- species
- stems
- tree size*
- visible root flare

* measured in inches in diameter at 4.5 feet above ground (or diameter at breast height [DBH])

Tree Inventory Input Fields and Definitions

The data fields definitions that were collected for each tree, stump, and planting site during the inventory are defined as follows:

- **Mapping coordinate.** X and Y coordinate locations.
- **Location.** The tree's location in relation to public ROW and/or public space.
- **Address**. The location of each street tree and planting site so that they can easily be identified for future maintenance work. Street trees and planting sites will be located using an address number, street name, side of address, and on street.
- **Species.** Trees were identified by genus and species, with the exception of genera such as *Amelanchier, Crataegus, Malus,* or *Prunus* where field identification of species is often not practical.
- **Diameter.** Diameter is measured in inches to the nearest tenth at 4-1/2 feet above the ground, or diameter-breast-height (DBH).
- **Multi-stem.** Trees were identified if they have multiple stems or are a single stem. (Measure the largest stem and record DBH)
- **Condition - canopy.** In general, the health and structure of each tree was recorded in one of the following categories based on visible twig and foliage conditions at the time of the inventory and adapted from the rating system established by the International Society of Arboriculture:
  - Good—80% condition rating
  - Fair—60% condition rating
  - Poor—40% condition rating
  - Dead—0% condition rating
- **Condition - wood.** In general, the health and structure of each tree was be recorded in one of the following categories based on visible root, trunk, and scaffold branch conditions at the time of the inventory and adapted from the rating system established by the International Society of Arboriculture:
  - Good—80% condition rating
  - Fair—60% condition rating
  - Poor—40% condition rating
  - Dead—0% condition rating
- **Growing Space Type.** Growing space locations are categorized as:
  - Island—Sites surrounded by pavement or hardscape (e.g., parking lot, cul-de-sac).
  - Median—Sites located between opposing lanes of traffic.
  - Natural Area—Sites developed through natural growth instead of design or planning.
  - Open/Restricted—Open sites with restricted growing space on 2 or 3 sides.
  - Open/Unrestricted—Open sites with unrestricted growing space on at least 3 sides.
  - Raised Planter—Sites located in an above-grade or elevated planter.
  - Tree Lawn/Parkway—Sites located between the street curb and the public sidewalk.

- Unmaintained Area—Sites located in areas that do not appear to be regularly maintained.
- Well/Pit—Sites at grade level and completely surrounded by sidewalk.

- **Growing Space Size - Width.** The minimum dimension of the Growing Space Type recorded in feet. In areas where the width or length would not restrict the growth of the tree, 99' was used as a default number.
- **Growing Space Size - Length.** The maximum dimension of the Growing Space Type recorded in feet. In areas where the width or length would not restrict the growth of the tree, 99' was used as a default number.
- **Maintain Ground.** Sites that require ground maintenance (e.g. weeding).
  - **New Sidewalk**—Sidewalks that appear new will be noted.
  - **Visible Root Flare**—Root flares that are visible will be noted.
  - **Girdling Roots**—Girdling roots that are visible will be noted.
  - **Sidewalk Deflection**—Where trees are present, cracking or lifting of sidewalk pavement one inch or more is noted.
- **Primary Maintenance Need.** The following primary maintenance needs were determined based on ANSI A300 standard specifications:
  - Removal—Trees designated for removal have defects that cannot be cost-effectively or practically treated. The majority of the trees in this category have a large percentage of dead crown. All trees with safety risks that could be seen as potential threats to persons or property and seen as potential liabilities to the client would be in this category. This category includes large dead and dying trees that are high-liability risks as well as those that pose minimal liability to persons or property (such as trees in poor locations or undesirable species).
  - Tree Clean—These trees require selective removal of dead, diseased, dying, and/or broken wood to minimize potential risk. Priority of work should be dependent upon the *Risk* associated with the individual trees.
  - Young Tree Train—These are young trees that must be pruned to correct or eliminate weak, interfering, or objectionable branches in order to minimize future maintenance requirements. Generally, these trees may be up to 20 feet in height and can be worked with a pole pruner by a person standing on the ground.
  - Stump Removal—This category indicates a stump that should be removed. Lacking specific information on stump removal required by local code requirements per the client.
  - Plant Tree—During the inventory, vacant planting sites will be identified by street, address, and site number. The size of the site is designated as small, medium, or large (indicating the ultimate size that the tree will attain), depending on the growing space available and the presence of overhead wires. Lacking local code definitions, planting sites are determined based on standard specifications set forth in accepted technical journals and by the arboriculture industry.
- **Possible EAB Treatment.** Condition of ash trees were judged as suitable for possible treatment.
- **Overhead Utilities.** The inventory indicates whether overhead conductors or other utilities are present at the tree site that could result in conflicts with the tree.

- **Risk Assessment.** A Level 2 qualitative risk assessment was performed based on the ANSI A300 (Part 9) and the companion publication *Best Management Practices: Tree Risk Assessment*, published by the International Society of Arboriculture (2011). Trees can have multiple failure modes with various risk ratings. One risk rating per tree will be assigned during the inventory. The failure mode having the greatest risk will serve as the overall tree risk rating. The specified time period for the risk assessment is one year.
  - **Likelihood of Failure**—Identifies the most likely failure and rates the likelihood that the structural defect(s) will result in failure based on observed, current conditions.
    - Improbable—The tree or branch is not likely to fail during normal weather conditions and may not fail in many severe weather conditions within the specified time period.
    - Possible—Failure could occur, but it is unlikely during normal weather conditions within the specified time period.
    - Probable—Failure may be expected under normal weather conditions within the specified time period.
    - Imminent—Failure has started or is most likely to occur in the near future, even if there is no significant wind or increased load. The tree may require immediate action.
  - **Likelihood of Impacting a Target**—The rate of occupancy of targets within the target zone and any factors that could affect the failed tree as it falls toward the target.
    - Very low—The chance of the failed tree or branch impacting the target is remote.
      - Rarely used sites
      - Examples include rarely used trails or trailheads
      - Instances where target areas provide protection
    - Low—It is not likely that the failed tree or branch will impact the target.
      - Occasional use area fully exposed to tree
      - Frequently used area partially exposed to tree
      - Constant use area that is well protected
    - Medium—The failed tree or branch may or may not impact the target.
      - Frequently used areas that is partially exposed to tree on one side
      - Constantly occupied area partially protected from tree
    - High—The failed tree or branch will most likely impact the target.
      - Fixed target is fully exposed to tree or tree part
  - **Categorizing Likelihood of Tree Failure Impacting a Target**—The likelihood for failure and the likelihood of impacting a target are combined in the matrix below to determine the likelihood of tree failure impacting a target.

Likelihood of Failure	Likelihood of Impacting Target			
	Very Low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very Likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely

Improbable	Unlikely	Unlikely	Unlikely	Unlikely

- **Consequence of Failure—**The consequences of tree failure are based on the categorization of target and potential harm that may occur. Consequences can vary depending upon size of defect, distance of fall for tree or limb, and any other factors that may protect a target from harm. Target values are subjective and should be assessed from the client's perspective.
  - Negligible—Consequences involve low value damage and do not involve personal injury
    - small branch striking a fence
    - medium-sized branch striking a shrub bed
    - large tree part striking structure and causing monetary damage
    - disruption of power to landscape lights
  - Minor—Consequences involve low to moderate property damage, small disruptions to traffic or communication utility, or very minor injury.
    - small branch striking a house roof from a high height
    - medium-sized branch striking a deck from a moderate height
    - a large tree part striking a structure, causing moderate monetary damage
    - short-term disruption of power at service drop to house
    - temporary disruption of traffic on neighborhood street
  - Significant—Consequences involve property damage of moderate to high value, considerable disruption, or personal injury.
    - a medium-sized part striking a vehicle from a moderate or high height
    - a large tree part striking a structure resulting in high monetary damage
    - disruption of distribution primary or secondary voltage power lines, including individual services and street-lighting circuits
    - disruption of traffic on a secondary street
  - Severe—Consequences involve serious potential injury or death, damage to high-value property, or disruption of important activities.
    - injury to a person that may result in hospitalization
    - a medium-sized part striking an occupied vehicle
    - a large tree part striking an occupied house
    - serious disruption of high-voltage distribution and transmission power line disruption of arterial traffic or motorways
- **Risk Rating—**The overall risk rating of the tree will be determined based on combining the likelihood of tree failure impacting a target and the consequence of failure in the matrix below.

Likelihood of Failure	Consequences			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High

Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Trees have the potential to fail in more than way and can affect multiple targets.

Tree risk assessors will identify the tree failure mode having the greatest risk, and report that as the tree risk rating. Generally, trees with the highest qualitative risk ratings should receive corrective treatment first. The following risk ratings will be assigned:

- None—Used for planting and stump sites only.
- Low—The Low Risk category applies when consequences are "negligible" and likelihood is "unlikely"; or consequences are "minor" and likelihood is "somewhat likely". Some trees with this level of risk may benefit from mitigation or maintenance measures, but immediate action is not usually required.
- Moderate—The Moderate Risk category applies when consequences are "minor" and likelihood is "very likely" or "likely"; or likelihood is "somewhat likely" and consequences are "significant" or "severe." In populations of trees, Moderate Risk trees represent a lower priority than High or Extreme Risk trees.
- High—The High Risk category applies when consequences are "significant" and likelihood is "very likely" or "likely", or consequences are "severe" and likelihood is "likely". In population of trees, the priority of High Risk trees is second only to Extreme Risk trees.
- Extreme—The Extreme Risk category applies in situations where tree failure is imminent and there is a high likelihood of impacting the target, and the consequences of the failure are "severe". In some cases, this may mean immediate restriction of access to the target zone area to avoid injury to people.

- Notes. Additional information regarding disease, insect, mechanical damage, etc. can be included in this field.

Maintenance needs are based on *ANSI A300 (Part 1)* (ANSI 2008). Risk assessment and risk rating are based on *Best Management Practices: Tree Risk Assessment* (International Society of Arboriculture [ISA] 2011).

The data collected were provided in an electronic ESRI® shapefile, Access™ database, and Microsoft Excel™ spreadsheet.

Site Location Methods

Equipment and Base Maps

Inventory arborists use FZ-G1 Panasonic Toughpad® unit(s) and internal GPS receiver(s).

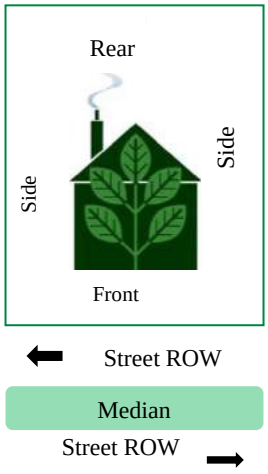
Base map layers were loaded onto these unit(s) to help locate sites during the inventory. The table below lists the base map layers, utilized along with source and format information for each layer.

Base Map Layers Utilized for Inventory

Imagery/Data Source	Date	Projection
Shapefiles Keith Johnson City of Somerville GIS Coordinator Capital Projects and Planning/Engineering Dept.	2018-2019	NAD 1983 StatePlane Massachusetts Mainland; Feet
6in Aerial Imagery City of Somerville GIS	2017	NAD 1983 StatePlane Massachusetts Mainland; Feet

Street ROW Site Location

Individual street ROW sites (trees, stumps, or planting sites) were located using a methodology that identifies sites by *address number, street name, or side*. This methodology was developed by DRG to help ensure consistent assignment of location.



Side values for street ROW sites.

Address Number and Street Name

The *address number* was recorded based on visual observation by the arborist at the time of the inventory (the address number was posted on a building at the inventoried site). Where there was no posted address number on a building, or where the site was located by a vacant lot with no GIS parcel addressing data available, the arborist used his/her best judgment to assign an address number based on opposite or adjacent addresses. An "X" was then added to the number in the database to indicate that it was assigned (for example, "37X Choice Avenue").

Sites in medians or islands were assigned an address number using the address on the right side of the street in the direction of collection closest to the site. Each segment was numbered with an assigned address that was interpolated from addresses facing that median/island. If there were multiple median/islands between cross streets, each segment was assigned its own address.

The *street name* assigned to a site was determined by street ROW parcel information and posted street name signage.

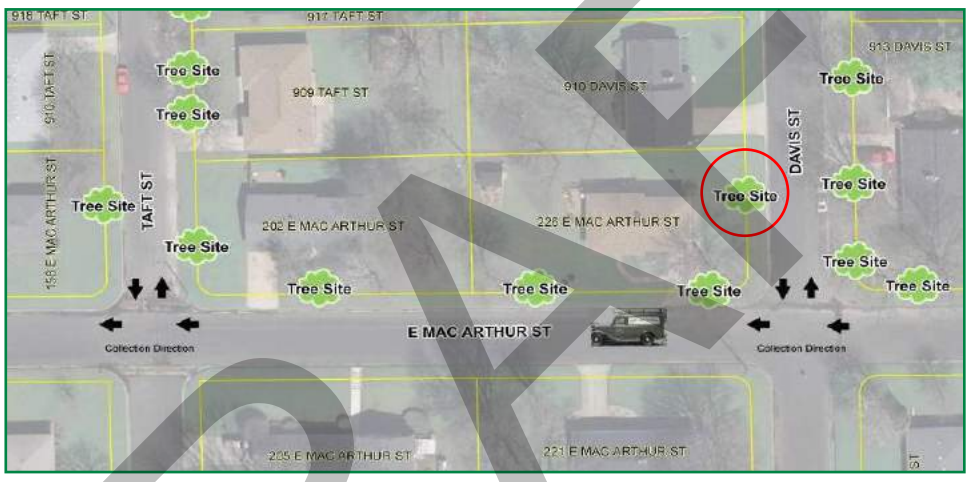
Side Value

Each site was assigned a *side value*. Side values include: *front*, *side*, *median* (includes islands), or *rear* based on the site's location in relation to the lot's street frontage. The *front side* is the side that faces the address street. *Side* is the name of the street the arborist walks towards or away from while collecting data. *Median* indicates a median or island. The *rear* is the side of the lot opposite the front.

Park and/or Public Space Site Location

Park and/or public space site locations were collected using the same methodology as street ROW site.

Site Location Examples



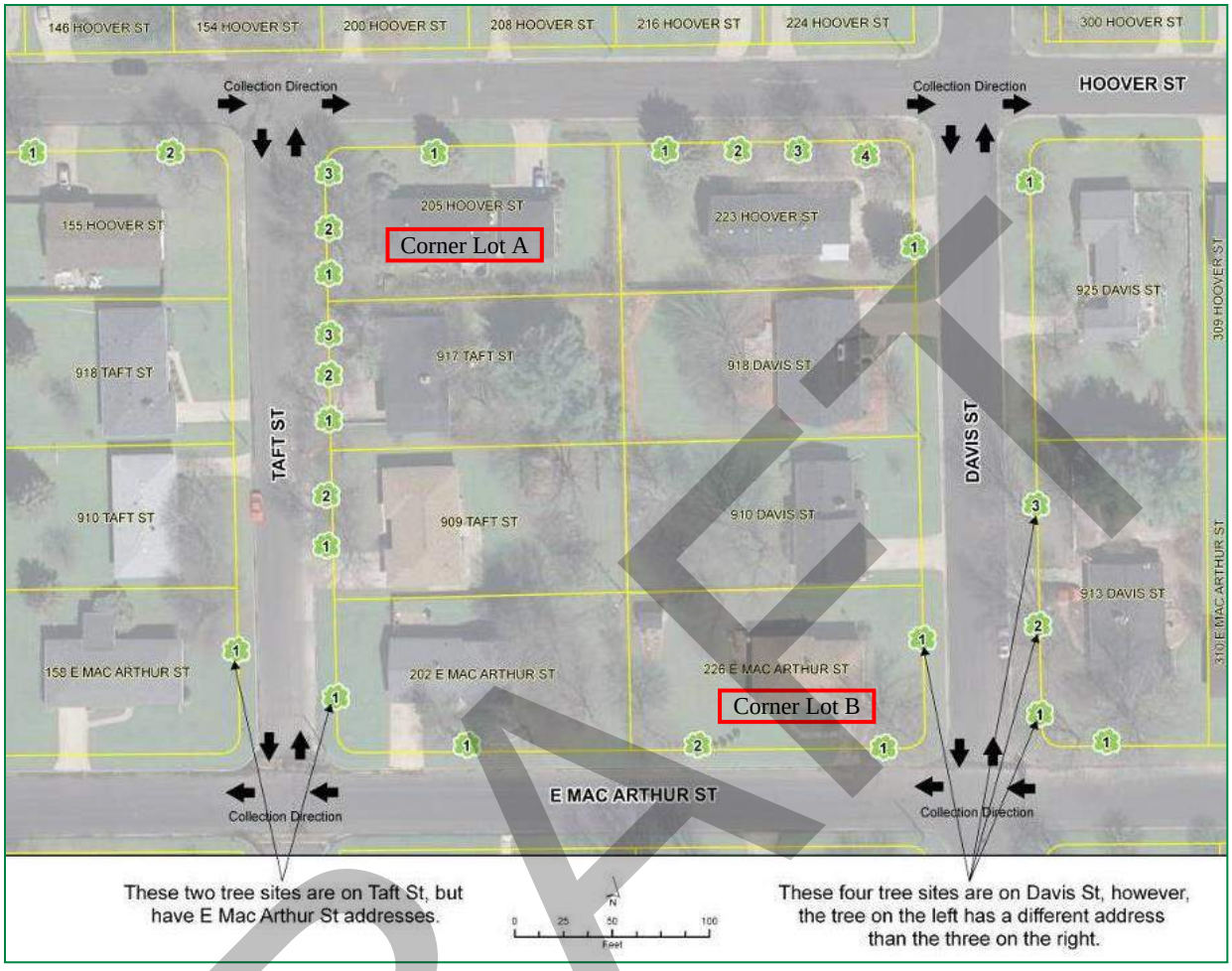
The tree trimming crew in the truck traveling westbound on E. Mac Arthur Street is trying to locate an inventoried tree with the following location information:

Address/Street Name: 226 E. Mac Arthur Street

Side: Side

On Street: Davis Street

The tree site circled in red signifies the crew's target site. Because the tree is located on the side of the lot, the *on* street is Davis Street, even though it is addressed as 226 East Mac Arthur Street.



Location information collected for inventoried trees at Corner Lots A and B.

Corner Lot A

Address/Street Name:	205 Hoover St.
Side:	Side
On Street:	Taft St.
Address/Street Name:	205 Hoover St.
Side:	Side
On Street:	Taft St.
.	
Address/Street Name:	205 Hoover St.
Side:	Side
On Street:	Taft St.
Address/Street Name:	205 Hoover St.
Side:	Front
On Street:	Hoover St.

Corner Lot B

Address/Street Name:	226 E Mac Arthur St.
Side:	Side
On Street:	Davis St.
Address/Street Name:	226 E Mac Arthur St.
Side:	Front
On Street:	E Mac Arthur St.
Address/Street Name:	226 E Mac Arthur St.
Side:	Front
On Street:	E Mac Arthur St.

List of Parks/Public Areas Collected in Somerville

- ALBION PLGD
- ALEWIFE BROOK RESERVATION*
- ALLEN ST PLGD & COMM GARDEN
- ARGENZIANO SCHOOL PLGD
- ASSEMBLY SQUARE BLOCK 2A PLAZA**
- AVON COMMUNITY GARDEN**
- BAILEY PARK
- BIKEWAY COMMUNITY GARDEN*
- BLESSING OF THE BAY*
- BROWN SCHOOL PLGD
- CENTRAL HILL PARK
- CHUCKIE HARRIS PARK
- CITY HALL
- COMMUNITY PATH*
- CONCORD SQUARE
- CONWAY FIELD
- CONWAY PARK
- CORBETT-MCKENNA PARK
- CREMIN PLGD
- CUMMINGS SCHOOLYARD
- DAVIS SQUARE PLAZA (STATUE PARK)
- DEPARTMENT OF PUBLIC WORKS
- DICKERMAN PLGD
- DILBOY FIELDS & STADIUM*
- DRAW 7 PARK*
- DURELL POCKET PARK & COMM GARDEN
- EAST LIBRARY
- EAST SOMERVILLE SCHOOLYARD
- EDGERLY EDUCATION CENTER SCHOOLYARD
- EDWARD LEATHERS PARK
- FIRE STATION
- FLORENCE PLAYGOUND
- FOSS PARK*
- GILMAN SQUARE
- GLEN PARK & CAPUANO/JAMES MCCARTHY FIELD
- GRIMMONS PARK
- HARRIS PLGD
- HEALY COMMUNITY SCHOOLYARD
- HENERY HANSEN PARK
- HODGKINS-CURTIN PARK
- HOYT-SULLIVAN PLGD
- KENNEDY SCHOOLYARD
- KENNEY PARK
- LEXINGTON PARK
- LINCOLN PARK
- MARSHALL STREET PLGD
- MAXPAC SQUARE AND DOG PARK**
- MILK ROW CEMETERY
- MORSE-KELLEY PLGD
- MYSTIC HOUSING DEVELOPMENT***
- NATHAN TUFTS/POWDERHOUSE PARK
- NORTH STREET VETERANS PLGD
- NUNZIATO FIELD
- OSGOOD PARK
- PALMACCI PLGD
- PAUL REVERE PARK
- PERKINS PLGD
- PERRY PARK
- POLICE & FIRE STATION
- POWDERHOUSE ROTARY
- PROSPECT HILL PARK
- QUINCY ST PARK
- SEVEN HILLS PARK
- SOMERVILLE COMM GROWING CENTER
- SOMERVILLE HIGH SCHOOL
- SOMERVILLE JUNCTION PARK
- SOMERVILLE LIBRARY
- SOUTH STREET FARM
- STONE PLACE PARK
- SYLVESTER BAXTER RIVERFRONT PARK*
- SYMPHONY PARK
- TRUM FIELD
- TRUM PLGD
- TUFTS PLAYING FIELD & COMM GARDEN***
- UNION SQUARE PLAZA
- VETERANS MEMORIAL CEMETARY
- VETERANS MEMORIAL RINK
- WALNUT STREET PARK
- WEST BRANCH LIBRARY
- WEST SOMERVILLE NEIGHBORHOOD SCHOOLYARD
- WINTER HILL SCHOOLYARD
- WOODSTOCK PLGD
- ZERO NEW WASHINGTON PARK

*Designates state-owned property

**Designates privately-owned public space

***Designates privately-owned property

APPENDIX D
SUGGESTED TREE SPECIES

Proper landscaping and tree planting are critical components of the atmosphere, livability, and ecological quality of a community's urban forest. The tree species listed below have been evaluated for factors such as size, disease and pest resistance, seed or fruit set, and availability. The following list is offered to assist all relevant community personnel in selecting appropriate tree species. These trees have been selected because of their aesthetic and functional characteristics and their ability to thrive in the soil and climate conditions throughout Zone 6 on the USDA Plant Hardiness Zone Map.

Deciduous Trees

Large Trees: Greater than 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Acer rubrum[d]	red maple	Red Sunset®
Acer saccharum	sugar maple	'Legacy'
*Aesculus flava**	yellow buckeye	
*Betula alleghaniensis**	yellow birch	
*Betula lenta**	sweet birch	
Betula nigra	river birch	Heritage®
Carpinus betulus	European hornbeam	'Franz Fontaine'
Carya illinoensis[d]*	pecan	
Carya lacinata[d]*	shellbark hickory	
Carya ovata[d]*	shagbark hickory	
*Castanea mollissima**	Chinese chestnut	
Celtis laevigata[s]	sugar hackberry	
Celtis occidentalis[d]	common hackberry	'Prairie Pride'
Cercidiphyllum japonicum	katsuratree	'Aureum'
Diospyros virginiana[ds]*	common persimmon	
*Fagus grandifolia**	American beech	
*Fagus sylvatica**	European beech	(Numerous exist)
Ginkgo biloba[ds]	ginkgo	(Choose male trees only)
Gleditsia triacanthos inermis[ds]	thornless honeylocust	'Shademaster'
Gymnocladus dioicus[ds]	Kentucky coffeetree	Prairie Titan®
Juglans nigra[ds]*	black walnut	
Larix decidua[s]*	European larch	
Liquidambar styraciflua[s]	American sweetgum	'Rotundiloba'
*Liriodendron tulipifera**	tuliptree	'Fastigiatum'
*Magnolia acuminata**	cucumbertree magnolia	(Numerous exist)
*Magnolia macrophylla**	bigleaf magnolia	
Metasequoia glyptostroboides	dawn redwood	'Emerald Feathers'
Nyssa sylvatica[ds]	black tupelo	
*Platanus occidentalis**	American sycamore	
Platanus × acerifolia	London planetree	'Yarwood'
Quercus alba[s]	white oak	

Large Trees: Greater than 45 Feet in Height at Maturity (Continued)

Scientific Name	Common Name	Cultivar
Quercus bicolor	swamp white oak	
Quercus coccinea[d]	scarlet oak	
Quercus lyrata[d]	overcup oak	
Quercus macrocarpa[ds]	bur oak	
Quercus montana[d]	chestnut oak	
Quercus muehlenbergii	chinkapin oak	
Quercus palustris[ds]	pin oak	
Quercus imbricaria	shingle oak	
Quercus phellos[ds]	willow oak	
Quercus robur[s]	English oak	Heritage®
Quercus rubra[ds]	northern red oak	'Splendens'
Quercus shumardii[d]	Shumard oak	
Styphnolobium japonicum[d]	Japanese pagodatree	'Regent'
Taxodium distichum[s]	common baldcypress	'Shawnee Brave'
Tilia americana	American linden	'Redmond'
Tilia cordata	littleleaf linden	'Greenspire'
Tilia × euchlora	Crimean linden	
Tilia tomentosa	silver linden	'Sterling'
Ulmus parvifolia[d]	Chinese elm	Allée®
Zelkova serrata	Japanese zelkova	'Green Vase'

Medium Trees: 31 to 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Aesculus × carnea	red horsechestnut	
Alnus cordata	Italian alder	
*Asimina triloba**	pawpaw	
Cladrastis kentukea	American yellowwood	'Rosea'
Corylus colurna[d]	Turkish filbert	
Eucommia ulmoides	hardy rubber tree	
Koelreuteria paniculata[ds]	goldenraintree	
Ostrya virginiana	American hophornbeam	
Parrotia persica	Persian parrotia	'Vanessa'
Phellodendron amurense	amur corktree	'Macho'
Pistacia chinensis	Chinese pistache	
Prunus maackii	amur chokecherry	'Amber Beauty'
Prunus sargentii	Sargent cherry	
*Pterocarya fraxinifolia**	Caucasian wingnut	
Quercus acutissima	sawtooth oak	
Quercus cerris	European turkey oak	
Sassafras albidum[d]*	sassafras	

Small Trees: 15 to 30 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Acer buergerianum	trident maple	Streetwise®
Acer campestre[s]	hedge maple	Queen Elizabeth™
Acer cappadocicum	coliseum maple	'Aureum'
Acer ginnala	amur maple	Red Rhapsody™
Acer griseum	paperbark maple	
Acer nigrum	black maple	
*Acer pensylvanicum**	striped maple	
Acer triflorum	three-flower maple	
Aesculus pavia[s]*	red buckeye	
Amelanchier arborea	downy serviceberry	(Numerous exist)
Amelanchier laevis	Allegheny serviceberry	
*Carpinus caroliniana**	American hornbeam	
Cercis canadensis[d]	eastern redbud	'Forest Pansy'
Chionanthus virginicus[s]	white fringetree	
Cornus alternifolia	pagoda dogwood	
Cornus kousa	Kousa dogwood	(Numerous exist)
Cornus mas	corneliancherry dogwood	'Spring Sun'
Corylus avellana	European filbert	'Contorta'
*Cotinus coggygria**	common smoketree	'Flame'
*Cotinus obovata**	American smoketree	
Crataegus phaenopyrum[d]*	Washington hawthorn	Princeton Sentry™
Crataegus viridis[d]	green hawthorn	'Winter King'
*Franklinia alatamaha**	Franklinia	
*Halesia tetraptera**	Carolina silverbell	'Arnold Pink'
Laburnum × watereri	goldenchain tree	
Maackia amurensis	amur maackia	
*Magnolia × soulangiana**	saucer magnolia	'Alexandrina'
*Magnolia stellata**	star magnolia	'Centennial'
*Magnolia tripetala**	umbrella magnolia	
Magnolia virginiana[s]*	sweetbay magnolia	Moonglow®
Malus spp.	flowering crabapple	(Disease resistant only)
Oxydendrum arboreum	sourwood	'Mt. Charm'
Prunus subhirtella	Higan cherry	'Pendula'
Prunus virginiana	common chokecherry	'Schubert'
*Staphylea trifolia**	American bladdernut	
Stewartia ovata	mountain stewartia	
*Styrax japonicus**	Japanese snowbell	'Emerald Pagoda'
Syringa reticulata[s]	Japanese tree lilac	'Ivory Silk'

* denotes species that are **not** recommended for use as street trees.
[d] denotes species that are drought tolerant (Clatterbuck and Wayne)
[s] denotes species that are tolerant to salt spray, saline soils, or both (Appleton et al. 2015)

Coniferous and Evergreen Trees

Large Trees: Greater than 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Abies balsamea	balsam fir	
Abies concolor	white fir	'Violacea'
Cedrus libani	cedar-of-Lebanon	
Chamaecyparis nootkatensis	Nootka falsecypress	'Pendula'
Cryptomeria japonica[s]	Japanese cryptomeria	'Sekkan-sugi'
× *Cupressocyparis leylandii*	Leyland cypress	
Ilex opaca[ds]	American holly	
Picea omorika	Serbian spruce	
Picea orientalis	Oriental spruce	
Pinus densiflora	Japanese red pine	
Pinus strobus[d]	eastern white pine	
Pinus sylvestris	Scotch pine	
Pinus taeda[d]	loblolly pine	
Pinus virginiana[d]	Virginia pine	
Psedotsuga menziesii	Douglas-fir	
Thuja plicata	western arborvitae	(Numerous exist)
Tsuga canadensis	eastern hemlock	

Medium Trees: 31 to 45 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Chamaecyparis thyoides	atlantic whitecedar	(Numerous exist)
Juniperus virginiana[ds]	eastern redcedar	
Pinus bungeana	lacebark pine	
Pinus flexilis	limber pine	
Pinus parviflora	Japanese white pine	
Thuja occidentalis	eastern arborvitae	(Numerous exist)

Small Trees: 15 to 30 Feet in Height at Maturity

Scientific Name	Common Name	Cultivar
Ilex × *attenuata*[d]	Foster's holly	
Pinus aristata	bristlecone pine	
Pinus mugo[ds]	mugo pine	

[d] denotes species that are drought tolerant

[s] denotes species that are tolerant to salt spray, saline soils, or both.

Zone 7 Trees

As climate shifts, there may be opportunities to plant a variety of species that were previously unsuited to Somerville's climate.

Trees Suitable for Zone 7

Scientific Name	Common Name	Cultivar	Mature Height
Acer nigrum	black maple		>45 feet
*Cedrus deodara**	deodar cedar		>45 feet
Chionanthus retusus	Chinese fringetree		15-30 feet
Ilex x[d]	Nellie R. Stevens holly	'Nelly R. Stevens'	15-30 feet
*Juglans regia**	English walnut		>45 feet
Lagerstroemia fauriei	Japanese crapemyrtle		31-45 feet
Lagerstroemia indica	common crapemyrtle	(Numerous exist)	15-30 feet
Magnolia grandiflora[s]*	southern magnolia		>45 feet
Pinus echinate[d]	shortleaf pine		>45 feet
Pinus elliottii	slash pine		>45 feet
Quercus hemisphaerica	Darlington oak		>45 feet
Quercus pagoda	cherrybark oak		>45 feet
Quercus prinus	chestnut oak		>45 feet
Quercus texana	Texas red oak		>45 feet
Quercus velutina[d]	black oak		>45 feet
Sorbus alnifolia	Korean mountainash	'Redbird'	31-45 feet
Stewartia koreana	Korean stewartia		15-30 feet
Toona sinensis	Chinese toon		31-45 feet

* denotes species that are **not** recommended for use as street trees.
[d] denotes species that are drought tolerant
[s] denotes species that are tolerant to salt spray, saline soils, or both.

Dirr's Hardy Trees and Shrubs (Dirr 2010), *Landscape Plants of the Southeast* (Halfacre & Shawcroft 1999), and *Manual of Woody Landscape Plants (5th Edition)* (Dirr 1998) were consulted to compile this suggested species list. Cultivar selections are recommendations only and are based on DRG's experience. Tree availability will vary based on availability in the nursery trade.

References

Appleton, Bonnie, et al. *Trees and Shrubs That Tolerate Saline Soils and Salt Spray Drift*. Virginia Polytechnic Institute and State University, 2015, pp. 6–9, *Trees and Shrubs That Tolerate Saline Soils and Salt Spray Drift*.

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Dirr, Michael A. *Manual of Woody Landscape Plants*. Stipes, 1998.

Halfacre, R. Gordon., and Anne R. Shawcroft. *Landscape Plants of the Southeast*. Sparks Press, 1999.

APPENDIX E
TREE PLANTING

Tree Planting

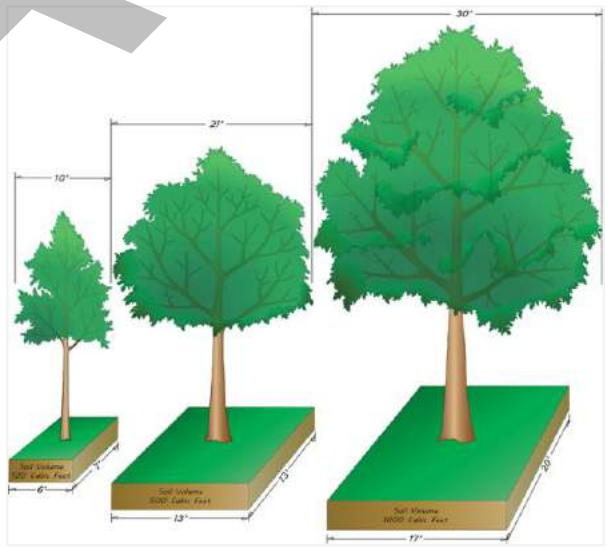
Planting trees is a valuable goal as long as tree species are carefully selected and correctly planted. When trees are planted, they are planted selectively and with purpose. Without proactive planning and follow-up tree care, a newly planted tree may become a future problem instead of a benefit to the community.

When planting trees, it is important to be cognizant of the following:

- Consider the specific purpose of the tree planting.
- Assess the site and know its limitations (i.e., confined spaces, overhead wires, and/or soil type).
- Select the species or cultivar best suited for the site conditions.
- Examine trees before buying them, and buy for quality.

Inventoried Street ROW Planting Space

The goal of tree planting is to have a vigorous, healthy tree that lives to the limits of its natural longevity. That can be difficult to achieve in an urban growing environment because irrigation is limited and the soils are typically poor quality. However, proper planning, species selection, tree planting techniques, and follow-up tree maintenance will improve the chance of tree planting success.



Minimum recommended requirements for tree sites is based on tree size/dimensions. This illustration is based on the work of Casey Trees (2008).

Findings

The inventory found 627 planting sites, of which 53% are designated for small-sized mature trees, 22% for medium-sized trees, and 25% for large-sized trees. Plant small-sized trees where the growing space is either too small for a medium- or large-sized species or where overhead utilities are present.

Tree Species Selection

Selecting a limited number of species could simplify decision-making processes; however, careful deliberation and selection of a wide variety of species is more beneficial and can save money. Planting a variety of species can decrease the impact of species-specific pests and diseases by limiting the number of susceptible trees in a population. This reduces time and money spent to mitigate pest- or disease-related problems. A wide variety of tree species can help limit the impacts from physical events, as different tree species react differently to stress. Species diversity helps withstand drought, ice, flooding, strong storms, and wind.

Somerville is located in USDA Hardiness Zone 6b, which is identified as a climatic region with average annual minimum temperatures between −5°F and 0°F. Tree species selected for planting in Somerville should be appropriate for this zone.

Tree species should be selected for their durability and low-maintenance characteristics. These attributes are highly dependent on site characteristics below ground (soil texture, soil structure, drainage, soil pH, nutrients, road salt, and root spacing). Matching a species to its favored soil conditions is the most important task when planning for a low-maintenance landscape. Plants that are well matched to their environmental site conditions are much more likely to resist pathogens and insect pests and will, therefore, require less maintenance overall.

The Right Tree in the Right Place is a mantra for tree planting used by the Arbor Day Foundation and many utility companies nationwide. Trees come in many different shapes and sizes, and often change dramatically over their lifetimes. Some grow tall, some grow wide, and some have extensive root systems. Before selecting a tree for planting, make sure it is the right tree—know how tall, wide, and deep it will be at maturity. Equally important to selecting the right tree is choosing the right spot to plant it. Blocking an unsightly view or creating some shade may be a priority, but it is important to consider how a tree may impact existing utility lines as it grows taller, wider, and deeper. If the tree's canopy, at maturity, will reach overhead lines, it is best to choose another tree or a different location. Taking the time to consider location before planting can prevent power disturbances and improper utility pruning practices.

A major consideration for street trees is the amount of litter dropped by mature trees. Trees such as *Acer saccharinum* (silver maple) have weak wood and typically drop many small branches during a growing season. Others, such as *Liquidambar styraciflua* (American sweetgum), drop high volumes of fruit. In certain species, such as *Ginkgo biloba* (ginkgo), female trees produce large odorous fruit; male ginkgo trees, however, do not produce fruit. Furthermore, a few species of trees, including *Crataegus* spp. (hawthorn) and *Gleditsia triacanthos* (honeylocust), may have substantial thorns. These species should be avoided in high-traffic areas.

Seasonal color should also be considered when planning tree plantings. Flowering varieties are particularly welcome in the spring, and deciduous trees that display bright colors in autumn can add a great deal of appeal to surrounding landscapes.

Davey Resource Group, Inc. "DRG" recommends limiting the planting of callery pear and red maple until the species distribution normalizes. Of the inventoried population they both already occupy 10% which is at the threshold of the recommended 10% species maximum. Norway maple makes up 14% of the population, however it is considered an invasive species in Massachusetts and should not be planted.

Tips for Planting Trees

To ensure a successful tree planting effort, the following measures should be taken:

- Handle trees with care. Trees are living organisms and are perishable. Protect trees from damage during transport and when loading and unloading. Use care not to break branches, and do not lift trees by the trunk.
- If trees are stored prior to planting, keep the roots moist.
- Dig the planting hole according to the climate. Generally, the planting hole is two to three times wider and not quite as deep as the root ball. The root flair is at or just above ground level.
- Fill the hole with native soil unless it is undesirable, in which case soil amendments should be added as appropriate for local conditions. Gently tamp and add water during filling to reduce large air pockets and ensure a consistent medium of soil, oxygen, and water.
- Stake the tree as necessary to prevent it from shifting too much in the wind.
- Add a thin layer (1–2 inches) of mulch to help prevent weeds and keep the soil moist around the tree. Do not allow mulch to touch the trunk.

Newly Planted and Young Tree Maintenance

Caring for trees is just as important as planting them. Once a tree is planted, it must receive maintenance for several years.

Watering

Initially, watering is the key to survival; new trees typically require at least 60 days of watering to establish. Determine how often trees should be irrigated based on time of planting, drought status, species selection, and site condition.

Mulching

Mulch can be applied to the growspace around a newly planted tree (or even a more mature tree) to ensure that no weeds grow, that the tree is protected from mechanical damage, and that the growspace is moist. Mulch should be applied in a thin layer, generally 1 to 2 inches, and the growing area should be covered. Mulch should not touch the tree trunk or be piled up around the tree.

Lifelong Tree Care

After the tree is established, it will require routine tree care, which includes inspections, routine pruning, watering, plant health care, and integrated pest management as needed.

The city should employ qualified arborists to provide most of the routine tree care. An arborist can determine the type of pruning necessary to maintain or improve the health, appearance, and safety of trees. These techniques may include: eliminating branches that rub against each other; removing limbs that interfere with wires and buildings or that obstruct streets, sidewalks, or signage; removing dead, damaged, or weak limbs that pose a hazard or may lead to decay; removing diseased or insect-infested limbs; creating better structure to reduce wind resistance and minimize the potential for storm damage; and removing branches—or thinning—to increase light penetration.

An arborist can help decide whether a tree should be removed and, if so, to what extent removal is needed. Additionally, an arborist can perform—and provide advice on—tree maintenance when disasters such as storms or droughts occur. Storm-damaged trees can often be dangerous to remove or trim. An arborist can assist in advising or performing the job in a safe manner while reducing further risk of damage to property.

Plant Health Care, a preventive maintenance process that keeps trees in good health, helps a tree better defend itself against insects, disease, and site problems. Arborists can help determine proper plant health so that the city's tree population will remain healthy and provide benefits to the community for as long as possible.

Integrated Pest Management is a process that involves common sense and sound solutions for treating and controlling pests. These solutions incorporate basic steps: identifying the problem, understanding pest biology, monitoring trees, and determining action thresholds. The practice of Integrated Pest Management can vary depending on the site and based on each individual tree. A qualified arborist will be able to make sure that the city's trees are properly diagnosed and that a beneficial and realistic action plan is developed.

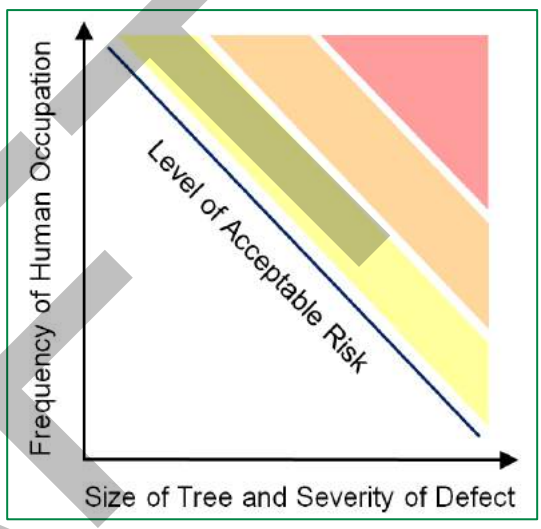
The arborist can also help with cabling or bracing for added support to branches with weak attachment, aeration to improve root growth, and installation of lightning protection systems.

Educating the community on basic tree care is a good way to promote the city's urban forestry program and encourage tree planting on private property. The city should encourage citizens to water trees on the ROW adjacent to their homes and to reach out to the city if they notice any changes in the trees, such as signs or symptoms of pests, early fall foliage, or new mechanical or vehicle damage.

APPENDIX F
RISK ASSESSMENT AND PRIORITY AND PROACTIVE MAINTENANCE

Risk Assessment

Every tree has an inherent risk of tree failure or defective tree part failure. During the inventory, Davey Resource Group, Inc. "DRG" performed a Level 2 qualitative risk assessment for each tree and assigned a risk rating based on the ANSI A300 (Part 9), and the companion publication *Best Management Practices: Tree Risk Assessment* (ISA 2011). Trees can have multiple failure modes with various risk ratings. One risk rating per tree will be assigned during the inventory. The failure mode having the greatest risk will serve as the overall tree risk rating. The specified time period for the risk assessment is one year.



- **Likelihood of Failure**—Identifies the most likely failure and rates the likelihood that the structural defect(s) will result in failure based on observed, current conditions.
  - Improbable—The tree or branch is not likely to fail during normal weather conditions and may not fail in many severe weather conditions within the specified time period.
  - Possible—Failure could occur but is unlikely during normal weather conditions within the specified time period.
  - Probable—Failure may be expected under normal weather conditions within the specified time period.
- **Likelihood of Impacting a Target**—The rate of occupancy of targets within the target zone and any factors that could affect the failed tree as it falls towards the target.
  - Very low—The chance of the failed tree or branch impacting the target is remote.
    - Rarely used sites
    - Examples include rarely used trails or trailheads
    - Instances where target areas provide protection
  - Low—It is not likely that the failed tree or branch will impact the target.
    - Occasional use area fully exposed to tree
    - Frequently used area partially exposed to tree
    - Constant use area that is well protected

- Medium—The failed tree or branch may or may not impact the target.
  - Frequently used areas that are partially exposed to the tree on one side
  - Constantly occupied area partially protected from the tree
- High—The failed tree or branch will most likely impact the target.
  - Fixed target is fully exposed to the tree or tree part

- **Categorizing Likelihood of Tree Failure Impacting a Target**—The likelihood for failure and the likelihood of impacting a target are combined in the matrix below to determine the likelihood of tree failure impacting a target.

Likelihood of Failure	Likelihood of Impacting Target			
	Very Low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very Likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

- **Consequence of Failure**—The consequences of tree failure are based on the categorization of target and potential harm that may occur. Consequences can vary depending upon size of defect, distance of fall for tree or limb, and any other factors that may protect a target from harm. Target values are subjective and should be assessed from the client's perspective.
  - Negligible—Consequences involve low value damage and do not involve personal injury.
    - Small branch striking a fence
    - Medium-sized branch striking a shrub bed
    - Large tree part striking structure and causing monetary damage
    - Disruption of power to landscape lights
  - Minor—Consequences involve low to moderate property damage, small disruptions to traffic or communication utility, or very minor injury.
    - Small branch striking a house roof from a high height
    - Medium-sized branch striking a deck from a moderate height
    - Large tree part striking a structure, causing moderate monetary damage
    - Short-term disruption of power at service drop to house
    - Temporary disruption of traffic on neighborhood street
  - Significant—Consequences involve property damage of moderate to high value, considerable disruption, or personal injury.
    - Medium-sized part striking a vehicle from a moderate or high height
    - Large tree part striking a structure resulting in high monetary damage
    - Disruption of distribution of primary or secondary voltage power lines, including individual services and street-lighting circuits
    - Disruption of traffic on a secondary street

- Severe—Consequences involve serious potential injury or death, damage to high-value property, or disruption of important activities.
  - Injury to a person that may result in hospitalization
  - Medium-sized part striking an occupied vehicle
  - Large tree part striking an occupied house
  - Serious disruption of high-voltage distribution and transmission power line disruption of arterial traffic or motorways

- **Risk Rating**—The overall risk rating of the tree will be determined based on combining the likelihood of tree failure impacting a target and the consequence of failure in the matrix below.

Likelihood of Failure	Consequences			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Trees have the potential to fail in more than one way and can affect multiple targets.

Tree risk assessors will identify the tree failure mode having the greatest risk, and report that as the tree risk rating. Generally, trees with the highest qualitative risk ratings should receive corrective treatment first. The following risk ratings will be assigned:

- None—Used for planting and stump sites only.
- Low—The Low Risk category applies when consequences are "negligible" and likelihood is "unlikely"; or consequences are "minor" and likelihood is "somewhat likely." Some trees with this level of risk may benefit from mitigation or maintenance measures, but immediate action is not usually required.
- Moderate—The Moderate Risk category applies when consequences are "minor" and likelihood is "very likely" or "likely"; or likelihood is "somewhat likely" and consequences are "significant" or "severe." In populations of trees, Moderate Risk trees represent a lower priority than High or Extreme Risk trees.
- High—The High Risk category applies when consequences are "significant" and likelihood is "very likely" or "likely," or consequences are "severe" and likelihood is "likely." In a population of trees, the priority of High Risk trees is second only to Extreme Risk trees.

- Extreme—The Extreme Risk category applies in situations where tree failure is imminent and there is a high likelihood of impacting the target, and the consequences of the failure are "severe." In some cases, this may mean immediate restriction of access to the target zone area to avoid injury to people.

Trees with elevated (Extreme or High) risk levels are usually recommended for removal or pruning to eliminate the defects that warranted their risk rating. However, in some situations, risk may be reduced by adding support (cabling or bracing) or by moving the target away from the tree. DRG recommends only removal or pruning to alleviate risk. But in special situations, such as a memorial tree or a tree in a historic area, Somerville may decide that cabling, bracing, or moving the target may be the best option for reducing risk.

Determination of acceptable risk ultimately lies with city managers. Since there are inherent risks associated with trees, the location of a tree is an important factor in the determination and acceptability of risk for any given tree. The level of risk associated with a tree increases as the frequency of human occupation increases in the vicinity of the tree. For example, a tree located next to a heavily traveled street will have a higher level of risk than a similar tree in an open field.

Priority Maintenance

Identifying and ranking the maintenance needs of a tree population enables tree work to be assigned priority based on observed risk. Once prioritized, tree work can be systematically addressed to eliminate the greatest risk and liability first (Stamen 2011).

Risk is a graduated scale that measures potential tree-related hazardous conditions. A tree is considered hazardous when its potential risks exceed an acceptable level. Managing trees for risk reduction provides many benefits, including:

- Lower frequency and severity of accidents, damage, and injury
- Less expenditure for claims and legal expenses
- Healthier, long-lived trees
- Fewer tree removals over time
- Lower tree maintenance costs over time

Regularly inspecting trees and establishing tree maintenance cycles generally reduce the risk of failure, as problems can be found and addressed before they escalate.

In this plan, all tree removals and Extreme and High Risk prunes are included in the priority maintenance program.

Proactive Maintenance

Proactive tree maintenance requires that trees are managed and maintained under the responsibility of an individual, department, or agency. Tree work is typically performed during a cycle. Individual tree health and form are routinely addressed during the cycle. When trees are planted, they are planted selectively and with purpose. Ultimately, proactive tree maintenance should reduce crisis situations in the urban forest, as every tree in the inventoried population is regularly visited, assessed, and maintained. DRG recommends proactive tree maintenance that includes pruning cycles, inspections, and planned tree planting.

APPENDIX G
INVASIVE PESTS AND DISEASES

In today's worldwide marketplace, the volume of international trade brings increased potential for pests and diseases to invade our country. Many of these pests and diseases have seriously harmed rural and urban landscapes and have caused billions of dollars in lost revenue and millions of dollars in clean-up costs. Keeping these pests and diseases out of the country is the number one priority of the United States Department of Agriculture's (USDA) Animal and Plant Inspection Service (APHIS).

Although some invasive species naturally enter the United States via wind, ocean currents, and other means, most invasive species enter the country with some help from human activities. Their introduction to the U.S. is a byproduct of cultivation, commerce, tourism, and travel. Many species enter the United States each year in baggage, cargo, contaminants of commodities, or mail.

Once they arrive, hungry pests grow and spread rapidly because controls, such as native predators, are lacking. Invasive pests disrupt the landscape by pushing out native species, reducing biological diversity, killing trees, altering wildfire intensity and frequency, and damaging crops. Some pests may even push species to extinction. The following sections include key pests and diseases that adversely affect trees in America at the time of this plan's development. This list is not comprehensive and may not include all threats.

It is critical to the management of community trees to routinely check APHIS, USDA Forest Service, and other websites for updates about invasive species and diseases in your area and in our country so that you can be prepared to combat their attack.

APHIS, Plant Health, Plant Pest Program Information
- www.aphis.usda.gov/plant_health/plant_pest_info

The University of Georgia, Center for Invasive Species and Ecosystem Health
- www.bugwood.org

USDA National Agricultural Library
- www.invasivespeciesinfo.gov/microbes

USDA Northeastern Areas Forest Service, Forest Health Protection
- www.na.fs.fed.us/fhp

Asian Longhorned Beetle

The Asian longhorned beetle (ALB, *Anoplophora glabripennis*) is an exotic pest that threatens a wide variety of hardwood trees in North America. The beetle was introduced in Chicago, New Jersey, and New York City, and is believed to have been introduced in the United States from wood pallets and other wood-packing material accompanying cargo shipments from Asia. ALB is a serious threat to America's hardwood tree species.

Adult Asian longhorned beetle

Photograph courtesy of New Bedford Guide 2011

Adults are large (3/4- to 1/2-inch long) with very long, black and white banded antennae. The body is glossy black with irregular white spots. Adults can be seen from late spring to fall depending on the climate. ALB has a long list of host species; however, the beetle prefers hardwoods, including several maple species. Examples include: *Acer negundo* (box elder); *A. platanoides* (Norway maple); *A. rubrum* (red maple); *A. saccharinum* (silver maple); *A. saccharum* (sugar maple); *Aesculus glabra* (buckeye); *A. hippocastanum* (horsechestnut), *Betula* (birch), *Platanus* × *acerifolia* (London planetree), *Salix* (willow), and *Ulmus* (elm).

Dutch Elm Disease

Considered by many to be one of the most destructive, invasive diseases of shade trees in the United States, Dutch elm disease (DED) was first found in Ohio in 1930; by 1933, the disease was present in several East Coast cities. By 1959, it had killed thousands of elms. Today, DED covers about two-thirds of the eastern United States, including Illinois, and annually kills many of the remaining and newly planted elms. The disease is caused by a fungus that attacks the vascular system of elm trees blocking the flow of water and nutrients, resulting in rapid leaf yellowing, tree decline, and death.

Branch death, or flagging, at multiple locations in the crown of a diseased elm

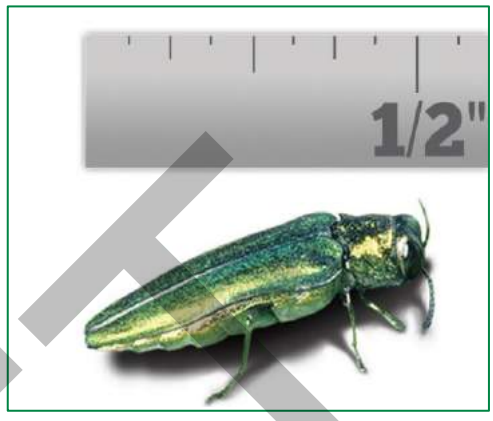
Photograph courtesy of Steven Katovich, USDA Forest Service, Bugwood.org (2011)

There are two closely-related fungi that are collectively referred to as DED. The most common is *Ophiostoma novo-ulmi*, which is thought to be responsible for most of the elm deaths since the 1970s. The fungus is transmitted to healthy elms by elm bark beetles. Two species carry the fungus: native elm bark beetle (*Hylurgopinus rufipes*) and European elm bark beetle (*Scolytus multistriatus)*.

The species most affected by DED is the *Ulmus americana* (American elm).

Emerald Ash Borer

Emerald ash borer *(EAB) (Agrilus planipennis*) is responsible for the death or decline of tens of millions of ash trees in 14 states in the American Midwest and Northeast. Native to Asia, EAB has been found in China, Japan, Korea, Mongolia, eastern Russia, and Taiwan. It likely arrived in the United States hidden in wood-packing materials commonly used to ship consumer goods, auto parts, and other products. The first official United States identification of EAB was in southeastern Michigan in 2002.



Close-up of the emerald ash borer

Photograph courtesy of APHIS (2011)

Adult beetles are slender and 1/2-inch long. Males are smaller than females. Color varies but adults are usually bronze or golden green overall with metallic, emerald-green wing covers. The top of the abdomen under the wings is metallic, purplish-red and can be seen when the wings are spread.

The EAB-preferred host tree species are in the genus *Fraxinus* (ash).

Herms et al. (2019) provides an overview of insecticide treatment options for controlling EAB.

Gypsy Moth

The gypsy moth (GM) *(Lymantria dispar*) is native to Europe and first arrived in the United States in Massachusetts in 1869. This moth is a significant pest because its caterpillars have an appetite for more than 300 species of trees and shrubs. GM caterpillars defoliate trees, which makes the species vulnerable to diseases and other pests that can eventually kill the tree.

Close-up of male (darker brown) and female (whitish color) European gypsy moths

Photograph courtesy of APHIS (2011b)

Male GMs are brown with a darker brown pattern on their wings and have a 1/2-inch wingspan. Females are slightly larger with a 2-inch wingspan and are nearly white with dark, saw-toothed patterns on their wings. Although they have wings, the female GM cannot fly.

The GMs prefer approximately 150 primary hosts but feed on more than 300 species of trees and shrubs. Some trees are found in these common genera: *Betula* (birch), *Juniperus* (cedar), *Larix* (larch), *Populus* (aspen, cottonwood, poplar), *Quercus* (oak), and *Salix* (willow).

Granulate Ambrosia Beetle

Adult granulate ambrosia beetle

Photograph courtesy of Paul M. Choate, University of Florida (Atkinson et al. 2011)

The granulate ambrosia beetle (*Xylosandrus crassiusculus*), formerly the Asian ambrosia beetle, was first found in the United States in 1974 on peach trees near Charleston, South Carolina. The native range of the granulate ambrosia beetle is probably tropical and subtropical Asia. The beetle is globally present in countries such as equatorial Africa, Asia, China, Guinea, Hawaii, India, Japan, New South Pacific, Southeast Indonesia, Sri Lanka, and the United States. In the United States, this species has spread along the lower Piedmont region and coastal plain to East Texas, Florida, Louisiana, and North Carolina. Populations were found in Oregon and Virginia in 1992, and in Indiana in 2002.

Adults are small and have a reddish-brown appearance with a downward facing head. Most individuals have a reddish head region and a dark-brown to black elytra (hard casings protecting the wings). Light-colored forms that appear almost yellow have also been trapped. A granulated (rough) region is located on the front portion of the head and long setae (hairs) can be observed on the back end of the wing covers. Females are 2–2.5mm and males are 1.5mm long. Larvae are C-shaped with a defined head capsule.

The granulate ambrosia beetle is considered an aggressive species and can attack trees that are not highly stressed. It is a potentially serious pest of ornamentals and fruit trees and is reported to be able to infest most trees and some shrubs (azalea, rhododendron) but not conifers. Known hosts in the United States include: *Acer* (maple); *Albizia* (albizia); *Carya* (hickory); *Cercis canadensis* (eastern redbud); *Cornus* (dogwood); *Diospyros* (persimmon); *Fagus* (beech); *Gleditsia* or *Robinia* (locust); *Juglans* (walnut); *Koelreuteria* (goldenrain tree); *Lagerstroemia* (crape myrtle); *Liquidambar styraciflua* (sweetgum); *Liriodendron tulipifera* (tulip poplar); *Magnolia* (magnolia); *Populus* (aspen); *Prunus* (cherry); *Quercus* (oak); and *Ulmus parvifolia* (Chinese elm). *Carya illinoinensis* (pecan) and *Pyrus calleryana* (Bradford pear) are commonly attacked in Florida and in the southeastern United States.

Xm Ambrosia Beetle

Xm ambrosia beetle

Photograph courtesy of Michael C. Thomas, Florida Department of Agriculture and Consumer Services (Rabaglia et al 2003)

The Xm ambrosia beetle (*Xylosandrus mutilatus*), is native to Asia and was first detected in the United States in 1999 in traps near Starkville, Mississippi. By 2002, the beetle spread throughout Missouri and quickly became well-established in Florida. The species also has been found in Alabama, northern Georgia, and Texas. In addition to its prevalence in the southeastern United States, the Xm ambrosia beetle is currently found in China, India, Indonesia, Japan, Korea, Malaya, Myanmar, Papua New Guinea, Sri Lanka, Taiwan, and Thailand.

This species generally targets weakened and dead trees. Since the beetle attacks small diameter material, it may be commonly transported in nursery stock. Female adults are prone to dispersal by air currents and can travel 1–3 miles in pursuit of potential hosts. This active capability results in a broad host range and high probability of reproduction. The species is larger than any other species of *Xylosandrus* (greater than 3 millimeters) in the U.S. and is easily recognized by its steep declivity and dark brown to black elytra (hard casings protecting the wings). Larvae are white and c-shaped with an amber colored head capsule.

Known hosts in the U.S. include: *Acer* (maple); *Albizia* (silktree); *Benzoin* (northern spicebush); *Camellia* (camellia); *Carpinus laxiflora* (looseflower hornbeam); *Castanae* (sweet chestnut); *Cinnamomum camphora* (camphor tree); *Cornus* (dogwood); *Cryptomeria japonica* (Japanese cedar); *Fagus crenata* (Japanese beech); *Lindera erythrocarpa* (spicebush); *Machilus thurnbergii* (Japanese persea); *Ormosia hosiei* (ormosia); *Osmanthus fragrans* (sweet osmanthus); *Parabezion praecox*; *Platycarpa*; and *Sweitenia macrophylla* (mahogany).

Hemlock Woolly Adelgid

The hemlock woolly adelgid (HWA, *Adelges tsugae*) was first described in western North America in 1924 and first reported in the eastern United States in 1951 near Richmond, Virginia.

Hemlock woolly adelgids on a branch

Photograph courtesy of USDA Forest Service (2011a)

In their native range, populations of HWA cause little damage to the hemlock trees, as they feed on natural enemies and possible tree resistance has evolved with this insect. In eastern North America and in the absence of natural control elements, HWA attacks both *Tsuga canadensis* (eastern or Canadian hemlock) and *T. caroliniana* (Carolina hemlock), often damaging and killing them within a few years of becoming infested.

The HWA is now established from northeastern Georgia to southeastern Maine and as far west as eastern Kentucky and Tennessee.

Oak Wilt

Oak wilt was first identified in 1944 and is caused by the fungus *Ceratocystis fagacearum*. While considered an invasive and aggressive disease, its status as an exotic pest is debated since the fungus has not been reported in any other part of the world. This disease affects the oak genus and is most devastating to those in the red oak subgenus, such as *Quercus coccinea* (scarlet oak), *Q. imbricaria* (shingle oak), *Q. palustris* (pin oak), *Q. phellos* (willow oak), and *Q. rubra* (red oak). It also attacks trees in the white oak subgenus, although it is not as prevalent and spreads at a much slower pace in these trees.

Oak wilt symptoms on red and white oak leaves

Photograph courtesy of USDA Forest Service (2011a)

Just as with DED, oak wilt disease is caused by a fungus that clogs the vascular system of oaks and results in decline and death of the tree. The fungus is carried from tree to tree by several borers common to oaks, but the disease is more commonly spread through root grafts. Oak species within the same subgenus (red or white) will form root colonies with grafted roots that allow the disease to move readily from one tree to another.

Pine Shoot Beetle

The pine shoot beetle (*Tomicus piniperda L.*), a native of Europe, is an introduced pest of *Pinus* (pine) in the United States. It was first discovered in the United States at a Christmas tree farm near Cleveland, Ohio in 1992. Following the first detection in Ohio, the beetle has been detected in parts of 19 states (Connecticut, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin).

Mined shoots on a Scotch pine

Photograph courtesy of USDA Forest Service (1993)

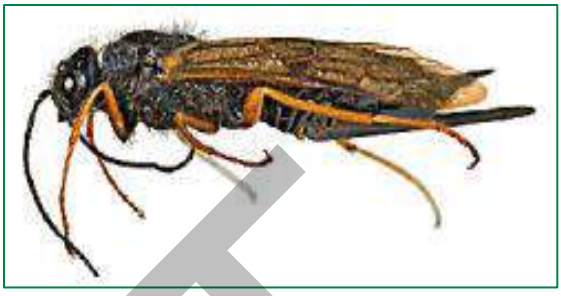
The beetle attacks new shoots of pine trees, stunting the growth of the trees. The pine shoot beetle may also attack stressed pine trees by breeding under the bark at the base of the trees. The beetles can cause severe decline in the health of the trees and, in some cases, kill the trees when high populations exist.

Adult pine shoot beetles range from 3 to 5 millimeters long, or about the size of a match head. They are brown or black and cylindrical. The legless larvae are about 5 millimeters long with a white body and brown head. Egg galleries are 10–25 centimeters long. From April to June, larvae feed and mature under the pine bark in separate feeding galleries that are 4–9 centimeters long. When mature, the larvae stop feeding, pupate, and then emerge as adults. From July through October, adults tunnel out through the bark and fly to new or 1-year-old pine shoots to begin maturation feeding. The beetles enter the shoot 15 centimeters or less from the shoot tip and move upwards by hollowing out the center of the shoot for a distance of 2.5–10 centimeters. Affected shoots droop, turn yellow, and eventually fall off during the summer and fall.

P. sylvestris (Scots pine) is preferred, but other pine species, including *P. banksiana* (jack pine), *P. nigra* (Austrian pine), *P. resinosa* (red pine), and *P. strobus* (eastern white pine), have been infested in the Great Lakes region.

Sirex Woodwasp

Sirex woodwasp (*Sirex noctillio*) has been the most common species of exotic woodwasp detected at United States ports-of-entry associated with solid wood-packing materials. Recent detections of sirex woodwasp outside of port areas in the United States have raised concerns because this insect has the potential to cause significant mortality of pines. Awareness of the symptoms and signs of a sirex woodwasp infestation increases the chance of early detection, thus increasing the rapid response needed to contain and manage this exotic forest pest.



Close-up of female Sirex Woodwasp

Photograph courtesy of USDA (2005)

Woodwasps (or horntails) are large robust insects, usually 1.0 to 1.5 inches long. Adults have a spear-shaped plate (cornus) at the tail end; in addition, females have a long ovipositor under this plate. Larvae are creamy white, legless, and have a distinctive dark spine at the rear of the abdomen. More than a dozen species of native horntails occur in North America.

Sirex woodwasps can attack living pines, while native woodwasps attack only dead and dying trees. At low populations, sirex woodwasp selects suppressed, stressed, and injured trees for egg laying. Foliage of infested trees initially wilts, and then changes color from dark green to light green, to yellow, and finally to red, during the three to six months following attack. Infested trees may have resin beads or dribbles at the egg laying sites, but this is more common at the mid-bole level. Larval galleries are tightly packed with very fine sawdust. As adults emerge, they chew round exit holes that vary from 1/8 to 3/8 inch in diameter.

Southern Pine Beetle

The southern pine beetle (SPB, *Dendroctonus frontalis*) is the most destructive insect pest of pine in the southern United States. It attacks and kills all species of southern yellow pines including *P. strobus* (eastern white pine). Trees are killed when beetles construct winding, S-shaped egg galleries underneath the bark. These galleries effectively girdle the tree and destroy the conductive tissues that transport food throughout the tree. Furthermore, the beetles carry blue staining fungi on their bodies that clog the water conductive tissues (wood), which transport water within the tree. Signs of attack on the outside of the tree are pitch tubes and boring dust, known as frass, caused by beetles entering the tree.

Adult southern pine beetles

Photograph courtesy of Forest Encyclopedia Network (2012)

Adult SPBs reach an ultimate length of only 1/8 inch, similar in size to a grain of rice. They are short-legged, cylindrical, and brown to black in color. Eggs are small, oval-shaped, shiny, opaque, and pearly white.

Spotted Lanternlfy

Profile of spotted lanternfly adult at rest

Photograph courtesy of Pennsylvania Department of Agriculture

The spotted lanternfly (SLF, *Lycorma delicatula*) is native to China and was first detected in Pennsylvania in September 2014. Spotted lanternfly feeds on a wide range of fruit, ornamental and woody trees, with tree-of-heaven being one of the preferred hosts. Spotted lanternflies are invasive and can be spread long distances by people who move infested material or items containing egg masses. If allowed to spread in the United States, this pest could seriously impact the country's grape, orchard, and logging industries.

Adult spotted lanternflies are approximately 1 inch long and one-half inch wide, and they have large and visually striking wings. Their forewings are light brown with black spots at the front and a speckled band at the rear. Their hind wings are scarlet with black spots at the front and white and black bars at the rear. Their abdomen is yellow with black bars. Nymphs in their early stages of development appear black with white spots and turn to a red phase before becoming adults. Egg masses are yellowish-brown in color, covered with a gray, waxy coating prior to hatching.

The spotted lanternfly lays its eggs on smooth host plant surfaces and on non-host material, such as bricks, stones, and dead plants. Eggs hatch in the spring and early summer, and nymphs begin feeding on a wide range of host plants by sucking sap from young stems and leaves. Adults appear in late July and tend to focus their feeding on tree-of-heaven (A. altissima) and grapevine (Vitis vinifera). As the adults feed, they excrete sticky, sugar-rich fluid similar to honeydew. The fluid can build up on plants and on the ground underneath infested plants, causing sooty mold to form.

Sudden Oak Death

The causal agent of sudden oak death (SOD, also known as *Phytophthora* canker disease), *Phytophthora ramorum*, was first identified in 1993 in Germany and the Netherlands on ornamental rhododendrons. In 2000, the disease was found in California. Since its discovery in North America, SOD has been confirmed in forests in California and Oregon and in nurseries in British Columbia, California, Oregon, and Washington. SOD has been potentially introduced into other states through exposed nursery stock. Through ongoing surveys, APHIS continues to define the extent of the pathogen's distribution in the United States and limit its artificial spread beyond infected areas through quarantine and a public education program.

Drooping tanoak shoot

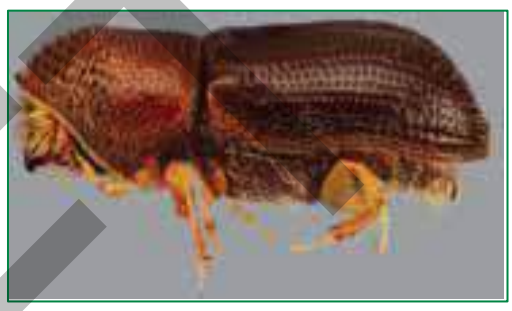
Photograph courtesy of Indiana Department of Natural Resources (2012)

Identification and symptoms of SOD may include large cankers on the trunk or main stem accompanied by browning of leaves. Tree death may occur within several months to several years after initial infection. Infected trees may also be infested with ambrosia beetles (*Monarthrum dentiger* and

M. scutellarer), bark beetles (*Pseudopityophthorus pubipennis*), and sapwood rotting fungus (*Hypoxylon thouarsianum*). These organisms may contribute to the death of the tree. Infection on foliar hosts is indicated by dark grey to brown lesions with indistinct edges. These lesions can occur anywhere on the leaf blade, in vascular tissue, or on the petiole. Petiole lesions are often accompanied by stem lesions. Some hosts with leaf lesions defoliate and eventually show twig dieback.

This pathogen is devastating to *Quercus* (oaks) but also affects several other plant species.

Thousand Cankers Disease



Walnut twig beetle, side view

Photograph courtesy of USDA Forest Service (2011b)

A complex disease referred to as Thousand Cankers disease (TCD) was first observed in Colorado in 2008 and is now thought to have existed in Colorado as early as 2003. TCD is considered to be native to the United States and is attributed to numerous cankers developing in association with insect galleries. TCD results from the combined activity of the *Geosmithia morbida* fungus and the walnut twig beetle (WTB, *Pityophthorus juglandis*). The WTB has expanded both its geographical and host range over the past two decades, and coupled with the *Geosmithia morbida* fungus, *Juglans* (walnut) mortality has manifested in Arizona, California, Colorado, Idaho, New Mexico, Oregon, Utah, and Washington. In July 2010, TCD was reported in Knoxville, Tennessee. The infestation is believed to be at least 10 years old and was previously attributed to drought stress. This is the first report east of the 100th meridian, raising concerns that large native populations of *J. nigra* (black walnut) in the eastern United States may suffer severe decline and mortality.

The tree species preferred as hosts for TCD are walnuts.

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Tree Emergency Plan Worksheet

For: Urban and Community Foresters, Community Leaders, Public Works and Parks Departments, Planners, Councils, and other Public Officials

1. Early Warning System/Weather Forecasting Service — Use an early warning procedure to enhance mitigation: communicate with the National Weather Service, a consulting meteorological firm, a designated television weather channel, or the local police department. With a procedure in place, you should have at least three hours of lead time before most tree damaging weather strikes.

Staff Lead: _____
Contact Name:_____
Address:_____
Phone:_____
Mobile:_____
Fax:_____
Email:_____
Website:_____
Description of services provided:

2. Local Emergency Manager – Lead contact for a community and responsible for emergency planning and response activities.

Name: _____ **Phone:** _____
Mobile: _____

Role(s):

3. Public Relations Coordinator — This is the individual responsible for primary public relations, media contacts, citizen information and communications about the natural disaster. (Must have full knowledge of damage, community issues and capabilities, and be able to make decisions.)

Name: _____ **Phone:** _____
Mobile: _____

Alternate(s):
Name: _____ **Phone:** _____
Mobile: _____
Name: _____ **Phone:** _____
Mobile: _____

4. Disaster Planning and Response Team Members: Your team should include: mayor, selected department heads including specialists in public relations and purchasing, public works specialists (streets, wood utilization and disposal, fleet manager), utilities, parks department, other local government heads, meteorologist, local emergency managers. Include creative people on your team that can think beyond barriers that may be up. Get media involved in planning so they understand what your cleanup priorities are after a storm. Someone involved with public tree management should be part of the community emergency management team. It is critical to include individuals who can make fiscal and administrative decisions because this team will most likely serve in the storm operations command center.

Name:	Role/Responsibility: _
1.	Mayor
2.	Fire Chief
3.	Director of Public Works
4.	Utility Representative
5.	Public Relations Representative
6.	City Council
7.	County Emergency Management
8.	Police Chief
9.	Director of Parks
10.	
11.	
12.	
13.	
14.	
15.	
16.	
17.	
18.	
19.	

5. Available Disaster Response Staff and Crews: Identify and list all municipal staff and crews available for disaster response work. Consider forestry and parks departments, public works, engineering, streets and sanitation, etc. Where possible, establish teams that can be responsible for specific disaster response activities (primary route clearing, assistance to utility crews, manage debris staging sites, distribute equipment, etc.)

Staff Name:	Role/Responsibility:
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	
16.	
17.	
18.	
19.	
20.	

6. Emergency Call Out Procedure — phone contact tree for staff.

Name: _____ Will Contact — Name: _____
Phone: _____
Mobile: _____

Name: _____
Phone: _____
Mobile: _____

Name: _____
Phone: _____
Mobile: _____

Name: _____ Will Contact — Name: _____
Phone: _____
Mobile: _____

Name: _____
Phone: _____
Mobile: _____

Name: _____
Phone: _____
Mobile: _____

Name: _____ Will Contact — Name: _____
Phone: _____
Mobile: _____

Name: _____
Phone: _____
Mobile: _____

Name: _____
Phone: _____
Mobile: _____

Name: _____ Will Contact — Name: _____
Phone: _____
Mobile: _____

Name: _____
Phone: _____
Mobile: _____

7. Primary transportation and evacuation corridors and routes for emergency vehicles.

Identify and map for reference. Have map available and accessible, and review and update annually.

8. Critical power transmission corridor restoration sites (medical treatment centers).

Identify and map for reference. Have map available and accessible, and review and update annually.

9. Identify who is responsible for decision making and priority response setting for multiple life threatening situations.

Name:_____ Phone:_____
Pager:_____ Mobile:_____

10. Tree Damage Clean-up Priorities

— List areas that need attention after life threatening situations are abated. Share this information with key staff the will be answering phone calls from residents, businesses, etc. Create a work order form for use when receiving calls.

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11. Procedure for Debris Staging and Removal — Identify several areas for staging and processing debris. Establish a contract or agreement securing each site. Choose a processing site that is large, flat, well-drained and accessible to roads that can support truck weights of at least 9 tons per axle. Identify ways to protect significant trees or cultural resources during processing. Potential sites include undeveloped park, industrial, cemetery, fairgrounds, agency and state land. Large parking lots (even paved lots) work well. Remember to consider noise implications near residential areas. Identify multiple sites. Annually reconfirm access and availability to these sites. Make sure the site is large enough for safety considerations (flying debris from tub grinders), if possible, identify sites that can be secured (fencing).

Site 1 – Location: _____

Contact Name/Role:

Phone: Mobile:

Site 2 – Location: _____

Contact Name/Role:

Phone: Mobile:

Site 3 – Location: _____

Contact Name/Role:

Phone: Mobile:

12. Debris and Brush Removal from Private Property — Identify how you will address this issue. A major storm makes it difficult for private property owners to remove brush and debris. Make a decision at the municipal level allowing for debris collection. Determine if your city has adequate equipment and staff available to accomplish this often enormous task. It is critical that you provide guidelines for residents. Specify the types, amounts and piling arrangement of the materials that you will accept. Cities can also assist private homeowners who must contract with private companies for trimming and removal by preparing a list of companies that are licensed, professionally trained and insured.

Person Responsible: _____
Phone: _____ **Mobile:**_____

Minor Storm Policy:

Major Storm Policy:

Listing of available tree care companies:

13. Identify Wood Utilization Options – Develop a list of companies and resources that can process the wood material generated from storm damage. When possible, establish a contract for utilization services.

Wood Utilization Contract: **Company/Organization:**

Phone: Mobile:
Utilization Service Contract: Yes / No
Description of Service:

Wood Utilization Contract: **Company/Organization:**

Phone: Mobile:
Utilization Service Contract: Yes / No
Description of Service:

14. Equipment Listing (available in-house) — Develop a list of public works and parks department equipment and vehicles available for tree clean up work. Keep it current. Include wood chippers, aerial bucket trucks, refuse packers, loaders, supervisory vehicles, chain saws, barricade and lighting equipment, hand saws and pole pruners on the list.

Person Responsible: _____
Phone:_____ **Mobile:**_____

Equipment Available	Quantity	Department/Contact
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

15. Additional Equipment and Assistance Sources — In an emergency, your city administrator may authorize the lease or rental of additional equipment for storm clean-up work. Make a list of potential vendors and keep it current. For certain equipment and assistance needs, it is critical to establish an emergency contract. Guaranteed access to large tub grinders and multiple additional tree trimming crews would be services to guarantee via an emergency contract. The city administrator may also authorize tree contractors to supplement city crews. Assemble a list of licensed and insured potential tree service contractors. Your neighbor cities may be unaffected by a storm that strikes your city. Establish a system to contact neighbor cities that could send staff and equipment to assist you in cleaning up your city.

Person Responsible: _____

Phone:_____ **Mobile:**_____

Equipment Available	Quantity	Department/Contact
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Emergency Contract:

Organization: Contact Name:
Phone: Mobile:

Emergency Contract:

Organization: Contact Name:
Phone: Mobile:

Emergency Contract:

Organization: Contact Name:
Phone: Mobile:

16. Staff, Crew Organization and Equipment Needs – In an emergency, staff members may need to lead crews from other departments or of private contractors. Determine staff who can function in this manner.

Name	Crew#	Equipment Needed

17. Individual(s) Responsible for Record Keeping — This person does documentation and cost accounting during and after disasters. Note – define a specific accounting code for each storm event. If you define a specific code for each storm event, it will allow for effective accounting.

Name: Phone:
Mobile:

Name: Phone:
Mobile:

Storm Accounting Code:

18. Individual(s) Responsible for Damage Assessment and Damage Survey Reports — This person is familiar with FEMA and Division of Emergency Management procedures and prepares the reports needed for public assistance.

Name: Phone:
Mobile:

Name: Phone:
Mobile:

19. Disaster Budget (identify potential activities to anticipate costs)

Personnel Regular Time:
Overtime:
Equipment Owned:
Equipment Contracted:
Contracted Work:
Operational Supplies:
Disposal/Recycling:

Administrative Costs (Overhead):

20. Funding Information from Past Storms — review costs from past storms to anticipate costs for future storms and establish funding needs.

Storm: _____ **Date**: _____

Activity	**Cost**
Personnel Regular Time	
Overtime	
Equipment Owned	
Equipment Contracted	
Contracted Work	
Operational Supplies	
Disposal/Recycling	
Administrative Costs (Overhead)	
TOTAL	

Storm: **Date**: _____ _____

Activity	**Cost**
Personnel Regular Time	
Overtime	
Equipment Owned	
Equipment Contracted	
Contracted Work	
Operational Supplies	
Disposal/Recycling	
Administrative Costs (Overhead)	
TOTAL	

21. Individual(s) and/or Organization(s) responsible for community regreening efforts: Develop a list of contacts for use in efforts to regreen the community after storm events.

Name/Organization: Phone:
Mobile:
Organization Role:

Name/Organization: Phone:
Mobile:
Organization Role:

Name/Organization: Phone:
Mobile:
Organization Role:

Name/Organization: Phone:
Mobile:
Organization Role:

22. Listing of community and neighborhood groups that promote and support community regreening efforts

Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:
Group:	Representative:	Phone: Mobile:

23. Community urban forestry comprehensive management plan —

Comprehensive forest management is your best defense against storms. Well planted and cared for trees stand up to weather better than neglected trees. Develop or modify a forest management plan to include information related to disaster preparedness. Identify critical activities such as hazard tree removal, tree pruning cycles, annual tree care needs, etc.

Name: Completed:

24. Community tree risk management plan — A tree risk management plan will provide the community with a systematic approach to accurately identify moderate to high risk trees, an initiate the timely removal or corrective treatment of hazardous trees. Communities that carry out tree risk management strategies will likely see reductions in damage after storms. Go to: http://www.na.fs.fed.us/spfo/pubs/uf/utrmm/index.htm

Name: Completed:

25. Storm Damage Assessment – If a storm is significant enough to receive a formal disaster declaration, state and/or federal funding may be available. To assist communities in the process of applying for reimbursement for storm associated costs, it is important to be able to quickly develop an estimate of damage. Consider using the Storm Damage Assessment Protocol as a tool prior to a storm. This protocol allows a community to provide an assessment of damage in a simple, credible and efficient manner. Go to: http://www.umass.edu/urbantree/icestorm/

Name: Completed:

26. Contacts for additional assistance in natural disaster planning, response and recovery:

Name	Phone

Area or District Forester
University Extension Agent
Consulting Foresters

City Foresters of Neighboring Cities:

Other

(Worksheet Prepared by: Lisa Burban (USDA Forest Service), Jim Hermann (Minneapolis Park and Recreation Board), and Katie Himanga (Heartwood Forestry) – Updated May, 2006. Worksheet available on-line at: http://www.na.fs.fed.us/urban/ucfdisasters/tree_emerg_plan/treeemerplanwksheet.htm)